U.S. Army Corps
of Engineers
Seattle District

Centralia Flood Damage Reduction Project
Chehalis River, Washington

Draft General Reevaluation Report

July 2002

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Chehalis River, Washington

General Reevaluation Study

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EXECUTIVE SUMMARY

The Seattle District, U.S. Army Corps of Engineers (Corps) and Lewis County, Washington have collaborated to re-evaluate a previously authorized flood damage reduction project in the Chehalis River Basin. This general reevaluation study was conducted in response to Resolution 2581 of the U.S. House of Representatives Committee on Transportation and Infrastructure, which directed a review of past Corps report recommendations in the study area and a reevaluation of flooding and environmental problems and solutions.

The purpose of this General Reevaluation Report (GRR) is to document the planning and formulation of the recommended plan. The report also identifies requirements and responsibilities associated with project implementation, operation, and maintenance. The main text of the report summarizes major technical studies conducted. Technical appendices provide detailed descriptions of study methodologies and findings. The report is accompanied by an Environmental Impact Statement published under separate cover.

A setback levee alternative that includes levees on the Chehalis and Skookumchuck Rivers was combined with a new formulation of the previously authorized modification to Skookumchuck Dam, non-structural flood damage reduction features, and environmental mitigation features to form the National Economic Development (NED) Plan and the recommended Locally Preferred Plan (LPP). The recommended plan (LPP) differs from the NED plan by providing more storage in Skookumchuck Dam; other features are the same. The local sponsor will incur all costs above those of the NED plan.

The recommended project will provide 100-year flood protection for the cities of Centralia and Chehalis, Washington. The selected plan provides estimated annual benefits of $8,765,000, including $6.5 million in flood related damages to structures and their contents, $2.1 million in annual avoided costs associated with the need to elevate Interstate Highway 5 without the project, and an annual reduction of $129,000 in traffic delays related to flooding. Annual economic costs are estimated at $7,220,000, resulting in annual net benefits of $1,545,000 and a positive benefit to cost ratio of 1.21 to 1. The NED Plan costs $6,700,000, providing net benefits of $2,065,000 at a benefit to cost ratio of 1.31 to 1. The recommended project is supported by the local sponsor, Lewis County, Washington.

Another benefit of the preferred alternative is that it provides the opportunity to establish restoration areas to enhance fish and wildlife habitat. Levee designs were optimized to maximize setback and to minimize impacts to sensitive environments. The setback levee alignment will give the Chehalis River an opportunity to overbank during certain flood events and re-establish riparian zones along the rivers banks while protecting the main infrastructure of the cities of Centralia and Chehalis from flood damages. Environmental project features were formulated to address limiting factors for fish and wildlife in the basin and were included in the recommended project to mitigate for all identified project impacts.

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1. INTRODUCTION

The cities of Chehalis, Centralia, and surrounding communities in Lewis and Thurston Counties, Washington have a long history of flooding and flood damages. These problems have been acknowledged and studied for many years. More recently, heightened environmental awareness and the potential listing of area aquatic species as threatened and endangered have resulted in a need for increased focus on development of flood control alternatives that minimize environmental impacts and that incorporate environmental features to mitigate any adverse impacts to fish and wildlife communities and habitats. This general reevaluation report documents the methods and findings of studies aimed to address these flooding and environmental problems.

The studies documented in this report are General Reevaluation Studies of the recommended project in the 1982 Feasibility Report titled *Centralia, Washington Flood Damage Reduction*. That report recommended modification of Skookumchuck Dam to provide for increased flood control storage. That recommendation was later found to be economically unjustified during the Preconstruction Engineering and Design (PED) phase and studies were terminated. The current General Reevaluation Study is in response to Congressional direction to reexamine previous recommendations for flood damage reduction in the vicinity of Centralia and Chehalis and to examine opportunities for ecosystem restoration.

1.1 Study Authority

Authority for the Centralia Flood Damage Reduction General Reevaluation Study and any subsequent construction is provided by the following Congressional actions:

Skookumchuck Dam Modification Project: Section 401(a) of 1986 Flood Control Act (PL 99-662) authorized construction of "works of improvement" substantially in accordance with the Report of the Chief of Engineers, dated 20 June 1984. The report was an interim report submitted (third in a series) under the Chehalis River and Tributaries Feasibility Study authority, originally authorized by a 19 April 1946 House of Representatives Flood Control Committee Resolution. A project to increase the dam to 28,500 acre-feet of storage was recommended and was authorized in 1986.

Chehalis River & Tributaries General Reevaluation Study: On 9 October 1998, the U.S. House of Representatives Committee on Transportation and Infrastructure adopted Resolution 2581, requesting a review of past Corps report recommendations with a view to determining if the recommendations should be modified "with particular reference to flood control and environmental restoration and protection, including non-structural floodplain modification." This resolution provided the authority and directive for the Corps to conduct this Flood Damage Reduction Study for the Chehalis River Basin.

1.2 Study Sponsorship

Although the City of Centralia was the project sponsor through the feasibility phase and initial PED work for the authorized Skookumchuck Dam Modification Project, it was Lewis County who requested that the Corps resume PED work with a view to combining additional measures with the authorized dam modification element to form a more complete flood damage reduction plan for the Centralia-Chehalis urban area. Lewis County has agreed to serve as local sponsor for project construction and to provide the appropriate cost sharing for PED and construction costs when necessary. PED work was resumed in July 1998.

1.3 Study Area

The study area includes the mainstem Chehalis River, its floodplain and tributaries from the South Fork Chehalis River confluence to Grand Mound, and includes the Cities of Centralia and Chehalis, in Lewis County, Washington. Tributaries entering the study area include the Skookumchuck and Newaukum Rivers, Salzer, China, Coal, Bunker, and Lincoln Creeks, among others. Studies along the Skookumchuck River extend upriver of Skookumchuck Dam and include the town of Bucoda in Thurston County.

1.4 Previously Authorized Project

The recommended project was authorized in 1986 with an estimated cost of $30.2 million (converted to 2001 price level). It proposed adding a 12-foot-diameter, 1,200-foot-long, low-level, gated discharge tunnel through the dam's north abutment and a bascule gate, 15-foot-high by 136-foot-wide, on the existing spillway crest. That project would provide up to 28,500 acre-feet (ac-ft) of flood storage and reduce the Skookumchuck River 200-year flood flow (1985 analysis) from 13,300 cfs to 6,700 cfs (a flood depth reduction of 2-5 feet along the Skookumchuck River in Centralia). With average annual benefits estimated at $4.3 million (2001 price level), the project had a benefit-to-cost ratio of 1.4 to 1.0.

PED work on the Centralia project was previously underway from February 1988 through August 1990. Negotiations were undertaken with the dam operator, PacifiCorp, to identify the maximum amount of flood storage they would agree to provide at Skookumchuck Dam, which was about 12,000 acre-feet. Earlier hydrologic, hydraulic, and economic studies were updated from the Feasibility Report and preliminary spillway design layouts and cost estimates were refined. Design work was suspended after studies indicated that the recommended plan lacked economic justification. A Wrap-Up Report was provided to the local governments in May 1992 that contained the useful information that had been generated by the project's design work.

1.5 Project History

There is a long history of study activities related to potential flooding on the Chehalis River and its tributaries. The following is a brief chronology of Federal study activities in the area.

TABLE 1-1 CHEHALIS RIVER AND TRIBUTARIES CHRONOLOGY OF FEDERAL STUDIES

1931	Corps of Engineers reports on the Chehalis Rivers and Tributaries were completed in 1931, 1935, and 1944 and all concluded that flood control improvements were not economically justified.
1944	In 1944 Congress authorized construction of a levee system to protect the communities of Hoquiam, Aberdeen, and Cosmopolis. The authorization expired in 1952 because local sponsors did not provide required items of local cooperation.
1965	Following serious flooding, study of the Chehalis River and Tributaries resumed in 1965 at the request of the city of Centralia and Lewis, Thurston, and Grays Harbor Counties. Studies found that large multi-purpose storage projects in the Chehalis Basin were not economically justified and that levee and or channel modifications along with small headwater dams should be studied further (including in the vicinity of Centralia-Chehalis). Enlargement of Skookumchuck Dam to provide flood control storage was determined to be not economically feasible.
1972	The Chehalis Basin study was divided into separate geographically based studies. Interim reports were published for each area. One of the areas was Centralia-Chehalis.
1974	Findings of further studies of flood control alternatives in the Centralia area found that an urban levee system was the only alternative that appeared economically justified.
1980	Analysis of the levee alternative from 1975-1980 resulted in a tentative recommendation for a levee system providing a 200-year level of protection for 2,080 acres in Centralia. Levees to provide protection for other areas, including Chehalis, were not economically justified. Centralia requested that the Corps review the potential for modifying Skookumchuck Dam to provide flood control.
1982	Further feasibility studies during 1981-1982 of modifying Skookumchuck Dam indicated that the dam modification would be a better solution than the urban levee system. The feasibility report, produced in 1982, recommended dam modifications (provision of a low-level flood control outlet, and raising the reservoir elevation to provide flood control storage).
1986	The Water Resources Development Act of 1986 authorized construction of the Skookumchuck Dam modification recommended in the 1982 feasibility report, *Centralia, Washington Flood Damage Reduction.*
1988-91	The Preconstruction Engineering and Design Phase followed the Feasibility Phase of study. In this phase, a limited reevaluation study was conducted to identify possible cost savings through design modifications and to update project economics to reflect revised mapping, revised water surface profiles, modified levee break assumptions, and revised stage-damage functions for frequent hydrologic events. Although project costs were significantly lowered through value engineering, the recalculation of economic benefits brought the benefit to cost ratio below unity. In 1991 the Division Engineer issued a public notice to terminate the study of the authorized modification to Skookumchuck Dam.
1990	The Salzer Creek Flood Damage Reduction Study, completed in September 1990, looked at flooding in the Salzer Creek basin, which occurs primarily from October through March. The primary plans considered were 6,000 feet of levee to protect the city of Centralia, and a small levee and pump plant to protect the cities of Centralia and Chehalis. The plan would protect portions of the cities of Centralia and Chehalis from the 100-year event flood on the Chehalis River and a larger event on Salzer Creek. The recommended plan consisted of a pump station, an approximately 1,000 foot long levee that would cross Salzer Creek at I-5 and which would prevent Chehalis River backwater flooding, and still allow Salzer creek to flow through. Local funding issues precluded this project from proceeding to construction.
1998	In 1998, the U.S. House of Representatives Committee on Transportation and Infrastructure adopted

	Resolution 2581, requesting a review of past Corps report recommendations with a view to determining if the recommendations should be modified "with particular reference to flood control and environmental restoration and protection, including non-structural floodplain modification."
1998	Seattle District and Lewis County initiated the Chehalis River and Tributaries General Reevaluation Study. The study explores structural and nonstructural flood control solutions.

1.6 Recent Local Activities

Following disastrous 1990 and 1996 flood events, a group of interested citizens in the spring of 1996 formed the Flood Action Council (FAC) to work on options to reduce or eliminate severe flooding in the Centralia-Chehalis area. With the help of a consultant team, the FAC developed a preliminary plan that combined modifying Skookumchuck Dam with overbank excavation at Centralia and additional upstream flood storage. Their proposal to form a Chehalis Basin (Lewis County) Flood Control District to implement that plan was rejected by the Lewis County Commissioners, because it did not meet legal criteria for creation. However, the Commissioners decided that the County would take the lead in identifying flood reduction measures and set up by ordinance a countywide Flood Control Zone District (FCZD)

Subsequently, Lewis County, using local & state funding and the same consultant team, conducted studies that identified possible modifications to the recommended project in the Chief's report that could result in a potentially economically justified project. Originally, these studies were developed to provide a community-based alternative to the Washington Department of Transportation's (WDOT) plan to raise the Interstate Highway 5 (I-5) grade near Centralia and Chehalis by up to 12 feet. Local governments wanted a plan for a comprehensive flood hazard management project that would provide flood relief as well as avoid raising I-5.

In May 1998, Lewis County completed a "Pre-Feasibility Analysis of Alternatives" report (similar in scope to a Corps reconnaissance study) that identified a plan that appeared to be economically justified and warranted further consideration. This plan was further refined in their November 1998 "Draft Interim Report". The version of the plan identified in that report combined dam modification (sluices through the spillway and a rubber, weir-type gate on top of the spillway) with overbank excavation near Centralia and flood bypass measures near Chehalis.

The Chehalis River Basin Partnership (CRBP) was also established in 1998 by an interlocal agreement among cities, towns, counties and tribes in the Chehalis River basin. The CRBP aims to implement state mandated watershed planning, particularly addressing water quality, water quantity, and fish habitat.

In April 1998, the Washington State Legislature provided through the Department of Transportation $600,000 to “establish alternatives for flood management and flood hazard reduction projects in the Chehalis basin”. A provision in the legislation required that a Technical Committee be established composed of WDOT, WDOE, Corps, FEMA, USGS, and “affected counties and tribes, and other entities with critical knowledge related to flood hazard reduction projects.” In accordance with those provisions, the then existing Chehalis Basin Coordinating Committee (which had been established in 1997) was reconstituted to form the Technical Committee. It established an Alternatives Subcommittee to identify and develop flood damage reduction measures and combine them into alternative plans for comparison with the alternative already developed by Lewis County. Most of the 1998 WDOT funding was provided to Lewis County to continue work on developing a flood damage reduction alternative for the Centralia-Chehalis area. In the 1999-2001 State budget an additional $300,000 was included to continue this effort, concentrating on coordination with the Corps of Engineers, negotiation with PacifiCorp on dam ownership transfer, the NEPA/SEPA process, and general project coordination.

In addition, in May 1999, the Washington State Legislature provided the WDOT $800,000 “for activities considered essential to understanding flood hazard reduction options for I-5, SR12 and other chronic flood hazards to transportation within the Chehalis watershed.” The WDOT and the local governments’ Executive Committee were required by the legislation to develop a Memorandum of Agreement to identify the tasks to be performed. A Memorandum of Agreement to “support community protection and salmon recovery efforts where possible” was signed.

1.7 Existing Projects in Study Area

1.7.1 Skookumchuck Dam

Skookumchuck Dam was completed in 1970 by Pacific Power and Light Company as agent for the owners, a group of eight public and private utilities. The dam is on the Skookumchuck River, 22 miles upstream from the river's confluence with the Chehalis River. The dam provides an assured water supply for the coal-fired Centralia Steam Electric Plant. The dam stores water during the late fall and winter for release during the low flow period of summer and early fall. The storage releases are carried instream for about 14 miles to a pumping plant that diverts water through a three-mile pipeline to the plant. In July 1982, the Federal Energy Regulatory Commission (FERC) approved an application for exemption from license from Pacific Power and Light Company for a 980-kilowatt (kW) generating facility at Skookumchuck Dam that uses existing excess discharges from the dam to generate power.

On 15 July 1998, Lewis County asked the dam owner, PacifiCorp, to begin formal discussions on transferring flood control operating authority and/or ownership rights for the dam and reservoir. They signed a MOA on 30 June 1999 that identifies the process and procedures to follow to investigate and ultimately, if favorable, transfer ownership of the dam and reservoir.

1.7.2 Long Levee

The Long Road Flood Damage Reduction project was constructed under authority of Section 205 of the 1948 Flood Control Act, as amended. The project is just south of the City of Centralia in Lewis County, Washington. The levee project ties into the embankment of Interstate 5 near milepost 81. The project is designed to protect approximately 100 acres of land, residential homes, a church, and a 100-bed convalescent center from floods up to about the 40-year event, which is a flood that has about a 2.5% chance of occurring or being exceeded on any year. The area protected is within the Long Road Diking District.

The project consists of a 2,200-foot earthfill levee stretching between the Tacoma Eastern Railroad (TERR) and Interstate 5 embankments in a reverse "L-shape". Excavated material from the interior of the reverse-L created a ponding area and provides storage for the project. To drain the interior storage area the project includes an outlet for ponding area with 2-30" culverts and flap gates and a ditch and berm with 2-30" culverts and flap gates.

1.7.3 Skookumchuck River Levee

Currently a levee exists along the Skookumchuck River, starting at Skookumchuck River mile[1] 2.0 for a length of .75 river miles. The levee averages 4 feet in height at an average slope of 1:5:1. The levee provides an estimated level of protection from the 100-year event plus 3 feet. The levee is composed of compacted fill and includes a maintenance road along the 12' top width.

1.7.4 Chehalis-Centralia Airport Levee

An existing levee protects the Chehalis-Centralia Airport, starting at Chehalis River mile 70.2 and extending for a length of 2.6 river miles. The levee averages 6' in height and has an average slope of 2:1. The levee provides estimated protection from the 100-year event less three feet. The levee is composed of compacted fill with a top width of 10' and no maintenance road.

1.7.5 Salzer Creek Levee

An existing levee runs along Salzer Creek starting at river mile .87 and extending upstream for .45 river miles. The levee has an average slope of 2:1 on the landside, 1.4:1 on the riverside. The levee has an average height of 9' and provides protection from the 100-year event less 2'. The levee is composed of compacted fill and has a 13' top width with a maintenance road.

[1] All references to river miles on the Chehalis and Skookumchuck Rivers (and other tributaries) start at the respective river's (in some cases, creek's) outlet. For example, Chehalis River mile 0.0 is at the outlet to Gray's Harbor. Skookumchuck River mile 0.0 is at the river's outlet to the Chehalis River. All other river mile references refer to the miles upstream from the outlet.

1.8 Prior Reports

A series of Corps of Engineers reports related to flood control in the Chehalis River Basin have been produced dating back to 1931. These reports are listed in Table 1.2 and are described in the following paragraphs.

Corps of Engineers reports on the Chehalis Basin completed in 1931, 1935, and 1944 all concluded that flood control improvements were not economically justified. However in 1944 Congress authorized a levee system to protect Aberdeen, Hoquiam, and Cosmopolis. The authorization expired in 1952. An interim report was transmitted to Congress in November 1978, recommending construction of a levee system to protect the south side of the Chehalis River at its mouth in the City of Aberdeen and town of Cosmopolis.

In the Chehalis-Centralia area, the lower 1,700 feet of Coffee Creek was modified in 1966 under the authority of Section 208 of the 1954 Flood Control Act. A floodplain information report was completed in June 1968 for the Chehalis River and Skookumchuck Rivers in the Chehalis-Centralia area. A hydraulic floodway study for the same area was completed in August 1974. A second hydraulic floodway study was completed in March 1976 covering the Chehalis and Newaukum Rivers in the vicinity of Chehalis. A comprehensive framework study of the water and related land needs of the Columbia River-North Pacific region was completed in 1972 under the direction of the Pacific Northwest Rivers Basin Commission, identifying the Chehalis-Centralia area as an area where levees should be constructed for urban flood damage reduction.

In 1982 the Corps released the Feasibility Report and Environmental Impact Statement for Centralia, Washington Flood Damage Reduction. The report recommended modifications to Skookumchuck Dam (provision of a low-level flood control outlet, and raising the reservoir elevation to provide flood control storage). This project was later found to be economically unjustified based upon updated economic studies during the PED phase. In February 1992 the Corps prepared the Skookumchuck Dam Modification Project, Centralia, Washington Wrap-Up Report, summarizing PED studies and data.

TABLE 1-2 CORPS OF ENGINEERS FLOOD CONTROL REPORTS IN STUDY AREA

Report	Date	Content
House Document 148 72nd Congress 1st Session	1931	Investigated improvements on the Chehalis River for navigation, flood control, hydropower development, and irrigation; concluded no improvements were justified
Preliminary Examination (not published as Congressional Document)	1935	Preliminary examination of flood control for the Chehalis River; concluded that flood control reservoir or channel improvements at Centralia-Galvin, Oakville, Malone, and Potter were not economically justified.
House Document 494 78th Congress 2nd Session	1944	Preliminary examination and survey for flood control on the Chehalis River and Tributaries considering construction of a levee system to protect Aberdeen, Cosmopolis, and Hoquiam; concluded: any additional flood control in the basin was not economically feasible. (Levee system was subsequently authorized by Congress in 1944. The authorization expired in 1952.)
Coffee Creek, Channel Excavation and Debris Removal under Section 208 of 1954 Flood Control Act	1965	Examined floodway problems along Lum Road in Centralia and recommended clearing and snagging on 1,660 feet of Coffee Creek (completed March 1966).
Floodplain Information, Chehalis and Skookumchuck River, Bucoda, Washington	1968	Delineated the floodplain along the Skookumchuck River from the Lewis/Thurston county line to about 1 mile upstream of Bucoda.
Floodplain Information, Chehalis and Skookumchuck Rivers, Centralia-Chehalis, Washington	1968	Delineated the floodplain along the Chehalis River from the Lewis/Thurston county line to Chehalis and along the Skookumchuck River from the mouth to the Lewis/Thurston county line.
Special Study, Suggested Hydraulic Floodway, Chehalis and Skookumchuck Rivers	1974	Delineated the suggested hydraulic floodway for the area covered by the June 1968 floodplain information report.
Special Study, Suggested Hydraulic Floodway Chehalis and Newaukum Rivers	1976	Delineated the floodplain and suggested hydraulic floodway for Chehalis River from Chehalis to Adna and the Newaukum River from its mouth to the I-5 bridge.

TABLE 1-2 CORPS OF ENGINEERS FLOOD CONTROL REPORTS IN STUDY AREA

Centralia, Washington Flood Damage Reduction Feasibility Report and Environmental Impact Statement	1982	Documents investigation of the feasibility of reducing flood damages in the cities of Centralia and Chehalis and surrounding areas. Recommended modification of the existing Skookumchuck Dam to provide flood control storage. (Recommendation later found to be economically unfeasible during PED phase).
Salzer Creek Flood Damage Reduction Report	1990	The Salzer Creek Flood Damage Reduction Study, completed in September 1990, looked at flooding in the Salzer Creek basin, which occurs primarily from October through March. The primary plans considered were 6,000 feet of levee to protect the city of Central, and a small levee and pump plant to protect the cities of Centralia and Chehalis. The plan would protect portions of the cities of Centralia and Chehalis from the 100-year event flood on the Chehalis River and a larger event on Salzer Creek. The recommended plan consisted of a pump station, an approximately 1,000 foot long levee that would cross Salzer Creek at I-5 and which would prevent Chehalis River backwater flooding, and still allow Salzer creek to flow through.
Skookumchuck Dam Modification Project, Centralia, Washington	1992	Preconstruction Engineering and Design (PED) work on the Skookumchuck Dam modification project was suspended in August 1990 when the updates of the projects economic analysis found the project unjustified. The wrap up report was prepared to document the technical work that had been completed at the time the PED work stopped.
Post Flood Study, Chehalis River at Centralia, Lewis County, Washington	1999	Study provides updated flood information on the discharge and stage for the 50-year and 100-year floods on the Chehalis River in the vicinity of the city of Centralia, Washington. The update was necessary due to significant changes in the flood frequency relations caused by a series of record floods over the previous 20 to 25 years. The study also addresses the effects of raising the road surface elevation of Interstate 5 in the Chehalis-Centralia corridor on flood levels in the area. Study found discharges and flood levels had significantly changed from those published in the 1980 FEMA report due to the change in the hydrologic record. The 100-year event at Grand Mound gauging station increased from 58,700 cfs to 74,300 cfs, or approximately .9 feet in stage.

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2. SCOPE OF GENERAL REEVALUATION STUDY

The Chehalis River General Reevaluation Study is a Post Authorization Study being conducted by the U.S. Army Corps of Engineers, Seattle District and Lewis County, WA. A general reevaluation study is a reanalysis of a previously completed and authorized study, using current planning criteria and policies, which is required due to changed conditions and/or assumptions. The results may affirm the previous plan; reformulate and modify it, as appropriate; or find that no plan is currently justified. The results of the study are documented in this General Reevaluation Report (GRR).

As documented in Section 1.4 of this report, in 1998, the U.S. House of Representatives Committee on Transportation and Infrastructure adopted Resolution 2581, requesting a review of past Corps report recommendations (including the project authorized for construction in WRDA 1986) with a view to determining if the recommendations should be modified “with particular reference to flood control and environmental restoration and protection, including non-structural floodplain modification.” Seattle District and Lewis County initiated the Chehalis River and Tributaries General Reevaluation Study to reevaluate previous and new configurations of structural and nonstructural flood control solutions and ecosystem restoration features. The study involved analysis of many technical areas including:

- Survey and mapping
- Hydrology and hydraulics
- Engineering Design
- Geotechnical Studies
- Economic Analysis
- Institutional Studies
- Real Estate Studies
- Environmental Studies
- HTRW Studies
- Cultural Resources Studies
- Cost Estimating
- Public Involvement

The scopes of these technical studies are summarized in the following sections, followed by an overview of risk-based flood damage reduction analysis and its application in the General

Reevaluation Study. Results of these studies are presented in detail in the respective technical appendices of this GRR and the EIS as appropriate. Those results that were key to the formulation and selection of the recommended plan are summarized throughout the following chapters in this report.

2.1 Survey and Mapping

To provide topographic input for the UNET1D computer models, an aerial photogrammetric survey was conducted for large portions of the Chehalis River basin including: Chehalis River floodplain from Cedarville (River Mile[2] (RM) 42) through Pe Ell (RM 107). The existing Thurston County 2-foot contour interval (CI) topographic mapping was used for the study areas in Thurston County. New 2-foot CI mapping was prepared for the following river reaches in Lewis County: 46 miles on the Chehalis River, 6 miles on the Skookumchuck River, 9 miles on the Newaukum River, about 5 miles in the Lincoln Creek valley, 9 miles in the Hanaford valley, 4 miles in the Sterns Creek valley, and 8 miles in the South Fork Chehalis River valley. The maps incorporate 2-foot contour intervals, planimetric details and extensive spot elevations (at grade breaks, road and railroad alignments) with a vertical accuracy of + 0.5’ foot. New topographic mapping of 1-foot contour interval was developed for the immediate vicinity of the existing Skookumchuck Dam, its intake and outlet structures. New river cross-sections were obtained by field measures.

2.2 Hydrology and Hydraulics

Hydrologic and hydraulic study tasks were completed to update, calibrate, and operate a hydraulic model of the Chehalis River valley and to support all hydrologic and hydraulic design work associated with layout and design of the potential project. Previous USACE archived databases and models were activated and updated as appropriate. The deregulated natural and existing condition flows on mainstem Skookumchuck and Chehalis rivers and tributaries associated with winter and spring floods of record were updated for use in hypothetical flood and dam regulation analyses. Historic and expected future changes in land use and population in the basin were researched and evaluated to assess influences on basin hydrology.

[2] See footnote 1 on page 8 for a description of “river miles” or “RM” as a framework for geographically locating project features.

The Chehalis basin frequency curves were reviewed and, particularly the low flow curves, revised, and hypothetical floods developed for the 2-, 10-, 25-, 50-, 100-, 200-, 500-year, and larger events. Work developed the magnitude of flow versus timing relationships and updated observed and hypothetical flood routings for use in hydraulic model.
Information was developed on the expected interior runoff for any areas protected by the potential alternatives. Risk and uncertainty associated with hydrologic data was identified.

Reservoir release options at Skookumchuck Dam were investigated regarding fishery impacts, river sedimentation, and water supply. The former reservoir temperature analyses were updated. The former Probable Maximum Flood and Standard Project Flood analyses were reviewed and updated using the new HMR57 and routed through the reservoir for site-specific dam safety analysis and spillway discharge adequacy. Reservoir storage rule curves and gate operating schedules were revised and updated. A preliminary data-collection plan and preliminary reservoir operating plan was developed. The analysis of power loss due to changed dam operation was revised and updated.

The existing UNET1D hydraulic model was updated to reflect revised hydrologic and topographic data. The model covers the river floodplain from the mouth at Aberdeen through Pe Ell (RM 107) with particular emphasis in the upper basin above Grand Mound (RM 60). The model includes 10 miles on the Black River, 22 miles on the Skookumchuck River, 9 miles on the Newaukum River, about 5 river miles in the Lincoln Creek valley, 9 river miles in the Hanaford Valley, and 8 river miles in the South Fork Chehalis River valley. An assessment of sediment transport in the river was prepared. After the models were calibrated to replicate past flood conditions accurately, the existing “without-project” flooding conditions were determined for the selected range of floods. In addition, an analysis was conducted to update the flood insurance floodplain and floodway maps for FEMA to publish on an interim basis until such time as a project(s) are constructed. At that time a revised version of the maps would be prepared as one of the work items during the construction phase.

The model was used to develop the “with-project” conditions and to formulate and screen potential flood damage reduction measures and help select the recommended project by identifying impacts associated with three alternative “with-project” conditions reflecting flood damage reduction measures and/or alternatives. Sediment sampling and analysis was performed to evaluate the impact of alternative projects on the sediment regime and to develop potential project operation and maintenance costs. A probabilistic risk and uncertainty analysis was performed for the selected project to help determine the recommended plan.

2.3 Economics

The economic analysis studies involved studies pertinent to an economic cost/benefit analysis of alternative flood damage reduction plans.[3] Expected annual flood damages were estimated under the existing (without-project) and the alternative with-project conditions. A narrative economic report is included as the Economic Technical Appendix to the GRR (Appendix E) with appropriate summary information included in the main report.

The principal controlling guidance of the analysis comes from USACE's "Planning Guidance Notebook", ER 1105-2-100, with specific guidance from the regulation's Appendix D – Economic and Social Considerations. Additional guidance on the risk-based analyses has been obtained from the U.S. Army Corps of Engineers' (USACE) EM 1110-2-1619, dated 1 August 1996, "Engineering and Design - Risk-based Analysis for Flood Damage Reduction Studies." Guidance on agricultural damages has been derived from USACE Water Resources Support Center's "National Economic Development Procedures Manual – Agricultural Flood Damage," IWR Report 87-R-10, dated October 1987.

The economic analysis was conducted in several phases. First project mapping was reviewed and all structures within the 500-year floodplain were provided a unique identifier number and entered into a database. This was followed by a field survey to obtain relevant data on the structures for entry into the database. A risk-based economic analysis was performed to develop the stage-damage function for each category of structures. The stage-damage functions and structures database were combined with water surface profiles from hydraulic analysis into the HEC-FDA model to calculate expected annual damages for each alternative. The damages reduced by each plan were then compared to the cost of each plan to identify the plan that maximizes net benefits. The results of these analyses are further described in the chapter on plan formulation.

[3] All economic analysis conducted for the general reevaluation study and presented in this report is based upon a 6.125% discount rate, 2002 price level, and 50-year period of analysis.

2.4 Engineering Design

Engineering design studies of alternative flood damage reduction measures were conducted in three segments. In the first segment, engineering design studies were performed at the minimum level needed to establish conceptual designs for alternative project features and elements that can to be compared with each other. The second segment involved further development of selected measures and alternatives for comparison and evaluation and the formulation of a recommended plan. The detailed design of the recommended plan (including mitigation features) was developed in the third segment, along with refinements to construction and operation and maintenance cost estimates and project construction schedules. All work was performed with a view to forming an appropriate basis for further design efforts, such as model tests and Feature Design Memorandums (FDM). The Cost Engineering Appendix (Appendix D) to the GRR provides all design data analyses, a written description of the design features of the recommended plan, plates, and cost estimates.

2.5 Geotechnical Studies

Geotechnical studies for this study include the investigation, exploration, and analysis of foundations and materials conditions related to the selection and design of the alternative flood damage reduction measures. Geotechnical effort was divided into two distinct elements: Skookumchuck Dam investigations and analyses and floodplain investigations and analyses.

2.5.1 Skookumchuck Dam Geotechnical Studies

The geotechnical effort for Skookumchuck Dam included a site-specific ground motion study due to increased estimations of the seismic risk in the Pacific Northwest. Past seismic studies were evaluated using present state-of-the-art practice and existing literature. A seismic analysis of the dam embankment stability based on dynamic loading methods followed the ground motion study. Work included a reservoir slope slide evaluation and investigation and analysis for a sluiceway(s) through the spillway. A soil exploration program was conducted beneath portions of the downstream dam embankment berm to determine liquefaction susceptibility of dam foundation silt and alluvium. An exploratory core drilling program was conducted to support rock cut slope stability and dewatering.

2.5.2 Floodplain Investigations Geotechnical Studies

The geotechnical effort for study area floodplains included a review of available geotechnical information from previous studies and intrusive field investigations to physically characterize materials to be excavated, stability of cut slopes, soil erosion potential, permeability of soils, seepage conditions, and potential borrow and materials sources. The exploration program involved auger drill borings, backhoe test pits, and the installation of piezometers. The Levee Plan Design Appendix (Appendix C) and the Skookumchuck Dam Design Appendix (Appendix B) to the GRR document the studies and their findings.

2.6 Institutional Studies

Institutional studies assess required institutional arrangements for funding project design, construction, operation, and maintenance; and identify, if any, necessary legislation requirements by the State of Washington to facilitate either project funding or construction. Institutional issues included:

- Coordination between the established governments was conducted to determine the legal entity that will serve as project sponsor for construction and operation
- Lewis County developed a legal analysis supporting their legal ability (or the legal ability of a new governmental entity) to provide the required items of local cooperation.
- Financial analysis in support of the construction recommendation was prepared by Lewis County to include a Statement of Financial Capability (SFC) and a Financing Plan (FP). The FP provides detail as to the anticipated funding authorities available to the Sponsor and its specific plans for financing its share of project costs. The Sponsor prepared the SFC and FP, with review by the Corps and Corps preparation of a Financial Capability Assessment (FCA) for inclusion in the GRR.

Institutional studies to be completed during PED include:

- Negotiations between Lewis County and PacifiCorp regarding possible transfer of dam ownership

- Coordination with the Federal Energy Regulatory Commission (FERC) regarding a new license or exemption from license covering the changes in the spillway and/or project operations.

2.7 Real Estate Studies

Real estate studies involved the identification, assessment, and appraisal of all real property interests required to support the conduct of the feasibility study and the recommendations of the GRR. Specific real estate study tasks included:

- Rights-of-Entry (ROE) were acquired from landowners for survey and mapping, design, geotechnical, and HTRW investigations, the cultural resources survey work, and site-specific environmental field studies
- A gross appraisal of project land costs (including relocations as necessary) was prepared. Work included detailed determination of cost of lands, easements, and rights-of-way for the recommended plan

A narrative Real Estate Plan is included as Appendix F to the GRR, describing the real estate requirements for the proposed project, sponsor's administrative acquisition costs, and Corps costs to review and advise the sponsor.

2.8 Environmental Studies

Environmental studies included environmental data collection and the determination of environmental impacts of alternative plans. Environmental study tasks included all activities required to comply with the National Environmental Policy Act (NEPA). Activities included literature searches and review of existing reports and field surveys to establish environmental baseline conditions; identification of future "without-project" conditions; determination of impacts of the alternatives; coordination with the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS); analysis of mitigation needs; development of potential habitat restoration opportunities; development and preparation of all appropriate NEPA documents; review of in-house reports; response to comments; and support to the project manager and others for the duration of the study.

2.8.1 EIS Preparation

The Corps prepared a draft and final EIS (published under separate cover) and public notice with assistance from the Sponsor. The EIS evaluated the environmental effects of the alternative plans and was coordinated with the Tribal, Federal, State, local governments and agencies, and interested groups and individuals. The Washington Department of Transportation and the Federal Highway Administration were cooperating agencies for the EIS.

2.8.2 Environmental Data Compilation

A literature search and compilation of existing data was accomplished to collect all pertinent information for use in assessing project impacts. Some of the information is in the Geographical Information System (GIS) format and was entered on the Seattle District GIS for overlaying on study and/or report maps. The GIS information will be used as input to PED.

2.8.3 Riparian Survey

The study team reviewed existing information on riparian habitat, vegetation type and structure, and floodplains. A field survey was completed to evaluate the quality and extent of riparian areas along the Chehalis River and tributaries in the project area. The study team evaluated potential adverse impacts to riparian areas for each alternative.

2.8.4 Wetland Survey

Existing information on wetlands in the project area was reviewed and evaluated. Field surveys were conducted to determine the extent of wetlands within the project area. Potential adverse impacts to wetlands were evaluated for each alternative.

2.8.5 Fisheries Survey

Existing information on fish distribution and use of the Chehalis River and tributaries was reviewed. Additional field investigations of instream habitats and fish distribution were conducted. Potential adverse impacts to fisheries were evaluated for each alternative. The study team conducted field surveys of instream habitats and fish use on the Skookumchuck River and fish use of portions of the Chehalis River during spawning, including the following:

- Spawner surveys (Skookumchuck R. and mainstem Chehalis)
- Habitat survey (above Skookumchuck dam)
- Off-channel habitat surveys (Skookumchuck R. and mainstem Chehalis) that assess functional connections w/streams, access; temperature; and changes in off-channel habitat resulting from potential water level changes
- Fish passage at dam
- Instream habitat effects of water level changes (proposed bypass reach)
- Investigation of potential habitat restoration opportunities

2.8.6 Environmental Mitigation Measures

The Government, in coordination with the Sponsor and Resource Agencies, preliminarily reviewed the scale of adverse environmental impacts associated with each alternative. The alternatives were evaluated to avoid, minimize and rectify potential adverse environmental impacts associated with each. Mitigation measures were identified only for all adverse environmental impacts of the recommended plan.

Preliminary alternative environmental mitigation designs were developed that focused on both offsetting project impacts and addressing limiting fish and wildlife habitat factors identified in the basin. These designs were developed in sufficient detail to develop cost estimates. The conceptual plans are documented in the EIS. An evaluation methodology was developed to evaluate the habitat outputs of alternative mitigation designs.

An incremental cost analysis was performed to assist with development of cost effective mitigation plans. The purposes of the incremental cost analysis were to determine and show variations in costs across alternative mitigation plans.

2.8.7 Endangered Species Act Coordination

The District prepared a biological assessment to identify possible impacts to species listed as threatened or endangered under the ESA. The BA, prepared in coordination with the USFWS, focused on species likely to be found in the project area. Limiting factors for endangered species in the area were identified and evaluated as part of the study. A range of environmental features throughout the study area was identified that addressed these limiting factors and could potentially be implemented for mitigation of negative project impacts.

2.8.8 Clean Water Act Section 404(b)(1) Evaluation

Project features will achieve the design level required to complete a 404(b)(1) analysis during the preconstruction engineering and design phase (PED). In all cases where a 404(b)(1) is needed, it will be fully developed on a site-specific basis prior to construction and will be completed prior to construction. The Corps will coordinate with the State Department of Ecology and the Chehalis Tribe to obtain Section 401 state water quality certification. Certification is usually done during PED (about 90% design level) when necessary information is developed. The Corps has requested a letter of support from the Department of Ecology.

2.8.9 Fish and Wildlife Coordination Act Report

The general reevaluation study includes coordination with, and studies conducted by, the USFWS, as required by the Fish and Wildlife Coordination Act (FWCA). The Corps developed a scope of work and transferred funds to the USFWS for interagency and tribal coordination, planning and evaluation of the impacts of alternative measures and plans on fish and wildlife resources, preparation of a minimum of two planning aid letters (PAL), and a draft and final Fish and Wildlife Coordination Act Report (FWCA) for inclusion in the EIS. The USFWS effort includes environmental data collection and evaluation of the environmental resources of the study area. The USFWS reviewed alternative plans and assessed the effect on the environment within the study area. The USFWS provided recommendations concerning the formulation of the alternatives. The USFWS also prepared a FWCA Report documenting its findings. The FWCA Report is included as an attachment to the EIS.

2.9 HTRW Studies

The Army Corps of Engineers Regulation 1165-2-132, Hazardous, Toxic and Radioactive Waste (HTRW) Guidance for Civil Works Projects, provides guidance for the consideration of issues associated with HTRW, which may be located within project boundaries or may affect or be affected by Corps Civil Works projects. This regulation outlines procedures to facilitate early identification and appropriate consideration of HTRW concerns in the reconnaissance; feasibility; preconstruction engineering and design, and operations, maintenance, repair, replacement, and rehabilitation phases of a project. Specific goals include (1) identification of level of detail for HTRW investigations and reporting for each phase of project (2) promotion of early detection and response by the appropriate responsible parties; (3) determination of viable options to avoid HTRW problems; (4) the establishment of a procedure for resolution of HTRW concerns, issues or problems.

For the general reevaluation study, Hazardous, Toxic, and Radiological Waste (HTRW) studies were conducted to determine the presence and character of contamination, if any, on lands needed for the project. Lands potentially needed for the project were reviewed, and sites with possible contamination identified in an initial screening. Further review of available information concerning those sites was conducted to estimate the volume and level of any contamination.

A preliminary HTRW assessment was conducted via the Internet and through coordination with the Department of Ecology Toxics Cleanup Program, SW Regional Office, for occurrence of HTRW on lands, including structures and submerged land, in the study area. The assessment included a project review, review of site literature and project features, database search, review of available records and aerial photography, site inspections and interviews. The following potential indicators were looked for: landfills, sumps, disposal areas, aboveground and underground storage tanks, vats, containers of unidentified substances, spills, seepage, slicks, odors, dead or stressed vegetation, water treatment plants, wells, ditches, abandoned buildings, and transport areas (such as boat yards, harbors, rail yards, airports, truck terminals, and fueling stations).

The assessment included a review of historical documentation; a review of regulatory listings and, if necessary, review of site files; site visits; and interviews with regulators, site owners and tenants where available or necessary. Regulatory lists reviewed included:

- EPA Lists: CERCLIS and the NPL
- Washington Lists: Confirmed and Suspected Contaminated Sites, State Cleanup Sites (MTCA), Voluntary Cleanup Sites, Hazardous Waste Generator Sites, Underground Storage Tanks, Leaking Underground Storage Tanks

The assessment covered all study regions, within the general vicinity of the proposed project or existing features proposed for significant modifications. Several site visits were conducted over the past few years and a preliminary site investigation was conducted for the recommended project that resulted in no findings of contaminated materials. The results of the field investigations, preliminary assessment, and data base search are included as an appendix to the EIS.

2.10 Cultural Resources Studies

Cultural resource studies were conducted to locate, identify, and evaluate historic and prehistoric cultural resources (CR) possibly impacted by alternative measures. Previous CR studies identified numerous CR sites within the larger project area. The general reevaluation study provided for completion of CR inventory (e.g., location and identification) and site evaluation in the study area. A preliminary evaluation of the effects of flood damage reduction alternatives upon historic properties was conducted.

These tasks were accomplished in consultation with the Washington State Historic Preservation Officer (SHIPO). If required, site data recovery would occur during the project construction phase. The CR data recovery strategy will be developed in accordance with a Memorandum of Agreement between the Seattle District, the SHPO, the Advisory Council on Historic Preservation, and the Chehalis Tribe.

2.11 Cost Estimating

Preliminary alternative cost estimates were prepared to assist in the development and screening of alternative flood damage reduction measures and plans.   The cost estimates included the preliminary construction costs for each alternative. Operation and maintenance costs were developed for each alternative as well. Mitigation and real estate costs were developed separately for the intermediate alternatives. Following initial screening and selection of an alternative, a detailed estimate of cost for the NED plan and recommended plan were prepared using MCACES software and are included in the Cost Engineering Appendix of the GRR (Appendix D). The MCACES cost estimates are included in Appendix D.

2.12 Public Involvement

Public involvement activities were related to developing public information on the study and obtaining public comments during the study process. The public involvement/outreach strategy consisted of (1) a series of workshops and public meetings, (2) workshop and meeting notices, news releases, and public information brochures; and (3) speaking engagements at community service clubs and local organizations by Corps and Lewis County personnel. The study included extensive review throughout the process by agencies at the Federal, state, local and tribal governmental level, special interest groups, and the general public. Those entities most directly involved in review included Washington Department of Fish &Wildlife, Washington Department of Transportation, Washington Department of Ecology, U.S. Fish and Wildlife Service, National Marine Fisheries Service, the Chehalis and Quinault Tribes, local governments, and interest groups. The Corps and Lewis County jointly conducted workshops and public meetings and participated in the community outreach engagements.

Coordination with several groups was maintained to facilitate dialogue among basin residents and interest groups. Several of these groups included the following:

- Chehalis River Basin Partnership (CRBP). The CRBP was established in 1998 by local governments in the Chehalis River basin to implement state mandated watershed planning. CRBP's goals are to coordinate cooperative efforts on: 1) improvement of water quality, 2) management of water supplies for farms, fish, industry, and people, 3) reduction of effects of flooding, 4) increase in recreational opportunities, and 5) increase in public awareness through education. Their primary focus is on preparing a watershed management plan that will address water quality, water quantity, and fish habitat. Coordination will be maintained with the CRBP to identify any information that they collect or develop that would be beneficial in PED. As PED develops the flood reduction measures, these will be discussed with the CRBP to obtain their comments on the project features, their potential impacts, and questions and concerns that should be addressed as part of design.

- Technical Committee & Alternatives Subcommittee. The Technical Committee was established in 1998 to advise on the use of the money appropriated by the State Legislature for flood hazard reduction projects in the Chehalis River basin. The Technical Committee in October 1998 formed an Alternatives Subcommittee to focus on identification of flood damage reduction measures and alternatives that could be discussed, screened, developed and compared with the one alternative previously developed by Lewis County.

A Notice of Intent (NOI) to prepare an EIS on structural and nonstructural alternatives to address flood damage reduction in the Centralia/Chehalis area and an announcement of public scoping meetings appeared in Federal Register Volume 64, Number 174, on 9 September 1999. A meeting notice describing the project, requesting comments, and announcing the dates, times, and locations of the public scoping meetings was mailed to interested individuals, groups, agencies, and tribes. A press release announcing the public meetings was sent to local media.

The Corps held two public scoping meetings on 28 and 29 September 1999 at WF West High School in Chehalis and Rochester High School in Rochester respectively. The Corps presented alternatives being considered to address flood damage reduction in the Centralia/Chehalis/I-5 urbanized area and provided opportunities for interested parties to identify issues and concerns associated with the proposed alternatives or to propose additional alternatives. Over 50 members of the public attended the two meetings and they were invited to comment orally or in writing. Over 75 comments were received at the meetings and in comment sheets sent in afterward.

The Corps continued to involve the local communities, state and Federal agencies and the tribes in the alternative selection process. In addition, since 1999 the Corps has presented project updates to the Chehalis River Basin Partnership, in order to keep the public informed of the process of the project. The Corps has also held several public information meetings regarding the selection of a recommended alternative.

3. WITHOUT PROJECT FLOODING AND FLOOD DAMAGE

This section describes historic, current, and expected flooding and flood damage in the study area without the implementation of a project.

3.1 Flooding

The cities of Centralia and Chehalis have been subject to repeated flooding for many years. This flooding has caused extensive damage to private and public property and periodic closure of critical transportation routes resulting in significant economic losses. In closing transportation routes, the flooding also significantly disrupts emergency response by local governments, impacting public safety adversely. Without implementation of flood hazard reduction measures, actions, or projects, the area will continue to suffer from damaging floods. The local economy will continue to experience depressing economic effects due to the damages and uncertainty associated with future floods.

Streamflow generated within the Chehalis River Basin originates primarily from rainfall, although snowmelt occasionally augments runoff in the highest elevation reaches of the basin. The average annual runoff of the Chehalis River at its mouth (drainage area 2,114 square miles) and at the USGS stream gage near Grand Mound (drainage area 895 square miles), are estimated to be 6.4 million acre-feet and 2.0 million acre-feet, respectively.

The flow in the rivers and creeks of the Chehalis River Basin show seasonal variation characterized by sharp rises of relatively short duration from October to March, corresponding to the period of heaviest rainfall. After March, the flows tend to gradually decrease to a relatively stable base flow, which is maintained from July into October.

Major flooding occurs during the winter season, usually from November through February, as the result of heavy rainfall occasionally augmented by snow melt. Flooding may be either widespread throughout the Chehalis River Basin or localized in subbasins. Some storms may cover the entire basin and cause widespread flooding. Other storms may center over the Willapa Hills and cause flooding of the upper Chehalis River or center over the Black Hills and Cascade Foothills and result in flooding of the Skookumchuck River and Newaukum River.

Table 3.1 lists the discharges and stages at three principal stream gauges chronologically for the ten greatest floods since 1971. This table shows that the record flood in January 1972 near Grand Mound was exceeded in November 1986, January 1990, and again in February 1996.

TABLE 3-1 ANNUAL FLOOD PEAKS AT 3 LOCATIONS SINCE 1971

Gage:	Chehalis near Grand Mound			Skookumchuck near Bucoda			Newaukum R. near Chehalis		
Year [1/]	Stage	Disch.	Rank	Stage	Disch.	Rank	Stage	Disch.	Rank
Jan. ' 71	17.29	40,800	7	15.82	6,630	6	11.99	8,390	8
Jan. ' 72	18.21	49,200	4	16.82	8,190	4	12.12	9,770	6
Jan. ' 74	16.88	37,400	8	15.30	5,950	8	11.17	8,440	7
Dec. ' 75	17.73	44,800	6	15.42	6,110	7	10.85	8,020	9
Dec. ' 77	16.79	36,500	9	16.18	7,170	5	12.49	10,300	5
Nov. ' 86	18.41	51,600	3	15.01	5,770	9	12.76	10,700	2
Jan. ' 90	19.34	68,700	2	17.33	8,540	2	12.75	10,400	3
Nov. ' 90	18.12	48,000	5	17.23	8,400	3	12.73	10,300	4
Dec. ' 94	16.97	35,900	10	14.02	4,100	13	10.62	6,040	28
Feb. ' 96	19.98	74,800	1	17.87	11,300	1	13.34	13,800	1

[1/] Flood dates are labeled by calendar year. The data is gathered by water years that begin in October and end in September. For instance, Jan. ' 90 is in water year 1990 and Nov. ' 90 is in water year 1991.
Source: Post Flood Study, USACE 1999.

3.2 Recent Floods

Brief descriptions of the three most recent, largest floods in the Centralia- Chehalis area (the, January 1990, November 1990, and February 1996 floods) are provided below.

3.2.1 January 1990 Flood

The January 1990 flood was primarily the result of a series of back-to-back storms accompanied by heavy rainfall over the 8-day period January 3-10. The heaviest rainfall occurred on the seventh day of the storm, January 9, causing extreme flooding because the rain fell on soils that were saturated from the preceding rainstorms.

The storm system was quite complex and included high winds and strong surges of precipitation. The Centralia climatological station recorded 8 inches of rain during the eight-day period. This eight day total precipitation represents 19 percent of the total yearly precipitation that is recorded at the station on the average. The most intense precipitation in the basin occurred near the headwaters of the Skookumchuck and Newaukum rivers.

The surges in precipitation resulted in more than one flood peak in many of the rivers and creeks in the basin. The streams did not return to base flow between storm surges. The early precipitation saturated the soils in the basin and added greatly to the runoff potential when the heaviest rains arrived on January 9.

3.2.2 November 1990 Flood

Above average precipitation in October and early November 1990 resulted in saturated soils that contributed to the flooding potential when the major storm arrived during the period of November 21-25. During the period between a smaller storm in early November and the major storm, wet weather accompanied by cool temperatures continued and snow levels descended to about the 1,000-foot elevation. The Cascade foothills averaged 6 inches at elevations of 1,000 to 2,000 feet; 12 inches at 2,000 to 3,000 feet; and 12-18 inches at 3,000 to 4,000 feet. The water content of the snow was generally 10 percent or higher. As a warm front moved through western Washington on Wednesday, November 21, snow changed to rain and temperatures rose. The warm front caused melting of snow up to elevations of 5,500 feet. Over the next 3 days, intense rain fell on drainages that were starting to swell from snow melt runoff; disastrous flooding resulted. A cold front moved in from the north on November 26, 1990, lowered freezing levels and diminished precipitation, finally ending the severe flooding.

3.2.3 February 1996 Flood

The February 1996 flood is the flood of record, to date, on all the major drainages in the Chehalis River Basin. Several of the main ingredients for a major storm flood were in place by February 5. The ground throughout the basin was at or near saturation from above average precipitation, which had fallen in the preceding weeks. In addition, snow had recently fallen as low as 500 feet above sea level during a cold snap. Third, warm, moist subtropical air was being transported from the Pacific Ocean into the Pacific Northwest. The freezing level in this subtropical air mass was well above 8,000 feet, which meant warm rains on the snow pack in the foothills.

Next, there was a strong polar jet stream with maximum wind speeds in its core in excess of 150 knots. These strong winds extended out into the central and western Pacific. Storms fed upon the stream and this powerful jet sustained and strengthened the storms as they moved in off the eastern Pacific. Also, the atmosphere was set up in a blocking pattern, which meant the major troughs and ridges around the Northern Hemisphere were stationary. The Pacific Northwest was situated between a major trough to the west and a major ridge to the east, ideal conditions for weather systems to be at maximum strength when they reached the area. The atmosphere remained in this general pattern for at least 96 hours during which copious amounts of rain fell and large quantities of water in the existing snow pack were released to flow into the rivers.

3.3 Flood Exceedance Frequency

To reflect the series of record floods over the last 25 years, the Corps recently updated their flood frequency curves for the Chehalis River in the vicinity of Centralia (USACE, 1997b). USACE previously published flood frequency curves for the Chehalis River for a 1980 Federal Emergency Management Agency (FEMA) report (ENSR, 1994), and made revisions to the curves in 1989 (USACE, 1992). Since 1980, there have been three floods of record, and several other major floods on the Chehalis River. Seattle District incorporated the data since 1980 and recomputed the frequency curves. The recomputed frequency curves data, shown as years of recurrence interval, are shown below. The recomputed frequency curves are significantly higher than those published in 1980 or 1989. Table 3-2 shows the updated peak discharge frequency data for selected locations in the study area. Table 3-3 shows the changes in flood recurrence interval from FEMA 1980 to the USACE Updates in 1989 and 1998.

TABLE 3-2 PEAK DISCHARGE FREQUENCY DATA FOR SELECTED LOCATIONS

Location	2-Year Flow (cfs)	10-Year Flow (cfs)	25-Year Flow (cfs)	50-Year Flow (cfs)	100-Year Flow (cfs)
Chehalis near Grand Mound	25,000	43,800	55,000	64,300	74,300
Skookumchuck at Mouth	5,200	9,000	10,600	11,900	13,000
Skookumchuck at Pearl St.	4,800	8,450	10,100	11,300	12,500
Skookumchuck near Bucoda	3,900	6,900	8,300	9,300	10,400
Chehalis at Mellen St.	18,400	32,700	41,400	49,000	57,200
Chehalis above Salzer Creek	17,900	31,900	40,400	47,600	55,700
Newaukum near Chehalis	5,800	9,300	11,200	12,400	13,800

TABLE 3-3 COMPARISONS OF FLOOD RECURRENCE INTERVALS AT GRAND MOUND

Year	Date	Maximum Flow (cfs)	Flood Recurrence Interval (years)		
		at Grand Mound Gage	USACE (1998 update)	USACE (1989 update)	FEMA (1980-present)
1996	Feb. 6	73,900	100	400	600
1990	Nov. 25	48,000	15	30	35
1990	Jan. 10	68,700	70	250	400
1972	Jan. 21	49,200	15	30	35

3.4 Risk-Based Flood Management Analysis

Risk involves exposure to a chance of injury or loss. Corps policy has long been to acknowledge risk and uncertainty in predicting floods and their impacts and to plan accordingly. Historically, planning relied on analysis of the expected long-term performance of flood management measures, on application of safety factors and freeboard, on designing for worse-case scenarios, and on other indirect solutions to compensate for uncertainty.

These indirect approaches were necessary because of both the lack of technical knowledge of the complex interaction of uncertainties in estimating hydrologic, hydraulic and economic factors and because of the complexities in performing the mathematics if the interactions were understood. However, with advances in statistical hydrology and the availability of analysis tools, it is now possible to describe the uncertainty in the choice of hydrologic, hydraulic, and economic functions, to describe the uncertainty in the parameters of the functions, and to describe explicitly in results when the functions are used.

Through this risk-based analysis (RBA), and with careful communication of the results, the public can be better informed about what to expect from flood management projects and thus can make better informed decisions. The RBA is integral to the Corps plan formulation process, which systematically reviews the characteristics of the problem to identify and evaluate promising candidate flood management measures or combinations of measures. The policies, methods and procedures for the RBA conducted in this effort are as detailed in ER1105-2-101, “Risked-Based Analysis for Evaluation of Hydrology/Hydraulics, Geotechnical Stability, and Economics in Flood Damage Reduction Studies” and in EM 1110-2-1619, “Risk-Based Analysis for Flood Damage Reduction Studies”.

3.4.1 Overview of RBA in Flood Damage Reduction Studies

The determination of expected annual damage (EAD) in a flood damage reduction study must take into account complex hydrologic, hydraulic, geotechnical and economic information. Specifically, EAD is determined by combining the discharge-frequency, stage-discharge, and stage-damage functions then integrating the resulting damage-frequency function. Uncertainties are present for each of these functions and are carried forth into the EAD computation. In addition, for the rivers being studied that have levees or alternatives that contain levee measures, geotechnical failure parameters become very critical to the analysis.

Once levees have failed and water enters the floodplain, then stages in the floodplain become more critical to the EAD computation than stages in the river channel. Additionally, economic efficiency of a plan or alternative is not the sole criterion for flood-damage reduction plan selection. Performance indices that assist in making informed decisions could include expected annual exceedance, long-term risk, and conditional probability of non-exceedance. These engineering performance indices allow for plan-to-plan comparison of risk of failure based on either the full range of floods or a specific flood. These indices are described below.

3.4.2 Flood Damage Reduction Analysis Model

The Corps primary model for performing flood damage reduction analysis is the Hydrologic Engineering Center's Flood Damage Reduction Analysis model (HEC-FDA, V1.2). The functions mentioned above are input into the model. HEC-FDA incorporates uncertainty for risk–based analysis using a Monte-Carlo simulation procedure. The two primary outputs from HEC-FDA include expected annual damage estimates and project performance statistics that are consistent with Corps guidance concerning the formulation of flood damage reduction plans.

3.4.3 Uncertainties Specific to the Chehalis Study

The Centralia Flood Reduction Project, as with any other flood damage reduction study, has critical uncertainties associated with the hydrologic, hydraulic, and economic data used to compute estimates of EAD and project performance statistics. The following discussion lists the important uncertainties for each of these disciplines and how they were (or were not) considered in this study.

3.4.3.1 Hydrologic Uncertainty

A number of factors contribute to hydrologic uncertainty. Such factors typically include limited or non-existent discharge data and uncertainty associated with existing discharge measurements. In situations where runoff modeling is used to estimate discharge, uncertainty exists in the rainfall-runoff relationship and is also associated with pertinent meteorological data (i.e., precipitation). In situations where streamflow is regulated by human activities, future regulation is subject to variability and uncertainty.

Hydrologic uncertainty is often expressed in terms of uncertainty in the discharge-probability relationship. Hydrologic uncertainty for this study was determined using one of two methods based on whether discharge at a given index location was significantly impacted by upstream regulation. Uncertainty in the discharge-probability relationship for unregulated flows was determined in the HEC-FDA program using Bulletin 17B procedures based on the mean, standard deviation, skew, and the equivalent record length. An equivalent record length of 70 years was used for index locations along the Chehalis River based on the period of record at the Grand Mound gaging station (USGS 12027500).

A similar procedure was used to characterize hydrologic uncertainty under existing conditions at index locations along the Skookumchuck River based on the observation that existing Skookumchuck reservoir operations have a generally limited impact on downstream peak annual discharge. An equivalent record length of 49 years was used for index locations along the Skookumchuck River based on an extension of existing Skookumchuck River discharge data using a two-gage comparison with Newaukum River discharge data. Hydrologic uncertainty at index locations along the Skookumchuck River under with project conditions is based on the assumption that future flood control regulation at the dam will significantly change the discharge-probability relationship within downstream reaches of the Skookumchuck River. Uncertainty in the discharge-probability relationship in this case was determined using the graphical exceedance probability method in the HEC-FDA program. The graphical method uses a statistical method called ordered events, which determines standard errors of points along the curve from the relationship of each of the estimates to adjacent points and the slope of the function.

3.4.3.2 Hydraulic Uncertainty

Hydraulic uncertainty generally relates to uncertainty in the stage-discharge relationship (rating curve) at the location(s) of interest along a stream network. Hydraulic uncertainty is influenced by a variety of factors including the inherent uncertainty of using a numerical model to represent a natural stream network and uncertainty in hydraulic parameters (i.e., channel cross-section information, Manning's roughness coefficient, representation of off-channel storage). A sensitivity analysis of the UNET modeling to certain hydraulic parameters was performed for this study to identify the parameters that appear to have the most significant influence on the stage-discharge relationship. For instance, the sensitivity analysis suggested that the volume associated with off-channel storage areas could be altered significantly with little apparent impact to the simulated stage-discharge relationships. Conversely and not surprisingly, simulated rating curves were quite sensitive to variations in the Manning's roughness coefficient.

The roughness coefficient was varied during the sensitivity analysis to capture both the uncertainty and variability (i.e., spatial and seasonal variability) of this parameter. Changes to the roughness coefficient were made by varying this parameter as a percentage of the value determined through model calibration. It was ultimately determined that a 40 percent variation of the roughness coefficient (i.e., +/- 20 percent from the calibrated values) provided a reasonable representation of the variability and uncertainty of this parameter. Results of the UNET modeling based on a 20 percent reduction of the roughness coefficient from the calibrated values were used to estimate the approximate lower confidence limit of the simulated rating curves. Conversely, results of the UNET modeling based on a 20 percent increase of the roughness coefficient from the calibrated values were used to estimate the approximate upper confidence limit of the simulated rating curves. Hydraulic uncertainty at the index locations was characterized by assuming that the overall range between the upper and lower bounds of the rating curves based on the 40 percent variation in roughness coefficient represents a range of four times the standard deviation of the uncertainty function (this assumes that roughly 95 percent of the uncertainty lies between the upper and lower confidence limits determined from the sensitivity analysis assuming a normal [Gaussian] distribution of the uncertainty function). Hydraulic uncertainty at the index locations was characterized in the HEC-FDA program by assuming that the error (uncertainty) function is characterized by a normal distribution centered about the expected rating curve with a standard deviation as determined from the sensitivity analysis.

3.4.3.3 Economic Uncertainty

The @Risk program (described in the Economic Technical Appendix) was used in the Phase II economic analysis to develop stage-damage relationships with uncertainty. Damages were estimated by impact area and by damage category. Economic variables with uncertainty used in the @Risk model include structure value, content value, foundation height, and depth-damage percentage.

3.4.4 Expected Annual Damages

The benefits and costs of a flood reduction study are expressed in average annual equivalents by performing appropriate discounting and annualizing. The expected value of annual damage is equivalent to integrating the annual damage-cumulative probability function. This function is developed by systematically combining the discharge-frequency, the stage-discharge and the stage-damage functions, including uncertainties. These functions are input into the HEC-FDA model. HEC-FDA incorporates uncertainty for risk –based analysis using a Monte-Carlo simulation procedure. Expected annual damages are computed for both without and with project conditions. Benefits are the difference between without and with project damages.

3.4.5 Expected Annual Exceedance Probability

The “expected annual exceedance probability” (AEP) is the probability of a project or alternative being exceeded in any one year. This performance parameter is derived by tracking the number of “failures” in the Monte Carlo sampling within HEC-FDA, divided by the number of samples. For example, if a levee has a 0.04 probability of being overtopped, it is said that in any given year it has a 1 in 25 chance of failing.

3.4.6 Long Term Risk

Long-term risk characterizes the probability of exceeding a plan or alternative in a specified period of time. This duration could be the proposed design life of the project, say 50 years, or the duration of a home mortgage, 30 years. For example, within the 30-year life of a conventional home mortgage, the probability of overtopping is 0.27 (or 27%). Such information is useful to help the public understand the risk of a given alternative and how it may apply directly to them.

3.4.7 Conditional Probability of Non-Exceedance

Conditional probability of non-exceedance is an index of the likelihood that an alternative will not be exceeded, given the occurrence of a specific hydrometeorological event. This index is similar to the AEP except the Monte Carlo sampling is performed at specific frequencies rather than sampling the entire range of frequencies. An example of the use of this index is, for the levee alternative X, the probability of containing the 0.01 or the 100-year event is 87%. This index is similar to the classic definition of “level of protection” (LOP). The LOP can be expressed as the average return period in years of the largest flood that can be contained by an alternative with a very high conditional non-exceedance probability, say 90% (see FEMA Certification below). Under this definition, the example levee alternative above does not meet the definition of a 100-year LOP.

3.4.8 FEMA Certification

The “Guidance on Levee Certification for the National Flood Insurance Program” dated 25 March 1997 was used to evaluate levee alternatives for FEMA certification. The guidance states that a levee is certifiable if the levee elevation meets FEMA criteria of 100-year flood elevation plus three feet of freeboard and achieves a conditional probability of non-exceedance of 90%. When the FEMA criteria results in a conditional probability of non-exceedance greater than 95%, the levee may be certified at the elevation corresponding to 95%.

3.5 Without Project Hydrology and Hydraulics

The study area was divided into eleven damage reaches for evaluating expected flood damages. Hydrologic and hydraulic modeling produced stage-discharge functions with uncertainty for the each damage reach. These damage reaches are listed in Table 3-4.

The historic changes in land use and population in the basin, expected future change, and relative influence on basin hydrology was researched and evaluated. It was determined that much of the upper basins will remain in forestry for the foreseeable future. The largest cities in the basin are Centralia and Chehalis whose populations are expected to grow in the next 15 years from 13,379 and 7,299 to 15,533 and 8,600 respectively. For all of Lewis County, the population has increased from 46,000 to 70,000 from 1972-1998. Expected land use and population changes were determined to not dramatically affect the runoff characteristics for the 895 square mile basin above Grand Mound.

TABLE 3-4 FLOOD ANALYSIS DAMAGE REACHES

Chehalis River

Reach Number	Extent of reach in terms of river miles (RM)	Index Cross-Section for Reach (RM) [1]	Description
Chehalis 1	RM 75.2 to RM 73	RM 74.02	Confluence of Chehalis/Newaukum Rivers to south end of airport
Chehalis 2	RM 73 to RM 71.5	RM 72.80	South end of airport to north end of airport
Chehalis 3	RM 71.5 to RM 69.2	RM 70.30	North end of airport to confluence of Chehalis River/Salzer Creek
Chehalis 4	RM 69.2 to RM 67.45	RM 68.67	Confluence of Chehalis River/Salzer Creek to Mellen St. Bridge
Chehalis 5	RM 67.45 to RM 66.9	RM 67.29	Mellen St. Bridge to confluence of Chehalis/Skookumchuck Rivers
Chehalis 6	RM 66.9 to RM 66.0	RM 66.30	Confluence of Chehalis/Skookumchuck Rivers to downstream end of proposed floodway excavation
Chehalis 7	RM 66.0 to RM 61.8	RM 65.20	Downstream end of proposed floodway excavation to Chehalis/Lincoln Creek confluence

1 - Index cross-sections for Chehalis River reaches are referenced to Chehalis River river mile (RM)

Skookumchuck River

Reach Number	Description of reach	Index Cross-Section for Reach (RM) [2]	Description
Skookumchuck 1	Town of Bucoda	RM 10.56	Town of Bucoda
Skookumchuck 2	RM 5.08 to RM 3.85	RM 5.08	Skookumchuck river mile 5.08 to confluence of Skookumchuck River/Hanaford Creek
Skookumchuck 3	RM 3.84 to RM 1.57	RM 2.415	Confluence of Skookumchuck River/Hanaford Creek to confluence of Skookumchuck River/Coffee Creek
Skookumchuck 4	RM 1.57 to RM 0.22	RM 0.98	Confluence of Skookumchuck River/Coffee Creek to limit of backwater effect from Chehalis River on Skookumchuck River

2 - Index cross-sections for Skookumchuck River reaches are referenced to Skookumchuck River river mile (RM)

The resultant stage discharge functions for each damage reach are provided in Table 3-5. The uncertainty (the standard deviation of error) was developed by varying Manning's n-value.

TABLE 3-5 STAGE DISCHARGE FUNCTIONS WITH UNCERTAINTY FOR CHEHALIS AND SKOOKUMCHUCK RIVERS

Reach Chehalis 1				
Index Cross-Section (RM) 74.02				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)*	Standard Deviation of Error (ft)
N/A	N/A	451	150.00	0.00
2	0.500	21,637	173.68	0.49
5	0.200	29,146	175.54	0.52
10	0.100	33,592	176.37	0.51
25	0.040	43,313	177.79	0.47
50	0.020	50,891	178.58	0.42
100	0.010	56,851	179.16	0.40
200	0.005	66,681	179.92	0.40
500	0.002	79,143	180.96	0.56
N/A	N/A	100,000	**183.00**	0.56

Reach Chehalis 2				
Index Cross-Section (RM) 72.80				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	451	149.95	0.00
2	0.500	20,231	172.34	0.57
5	0.200	28,237	174.47	0.54
10	0.100	32,582	175.32	0.51
25	0.040	42,186	176.77	0.47
50	0.020	48,736	177.53	0.50
100	0.010	52,747	178.12	0.54
200	0.005	60,574	178.89	0.73
500	0.002	67,166	180.06	1.02
N/A	N/A	90,000	**182.50**	1.02

** All of the elevations given in these tables are referenced to the NGVD 1929 vertical datum.*

Reach Chehalis 3				
Index Cross-Section (RM) 70.30				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	451	149.90	0.00
2	0.500	18,648	168.22	0.59
5	0.200	27,623	170.45	0.58
10	0.100	32,011	171.62	0.67
25	0.040	41,029	173.58	0.93
50	0.020	46,116	174.81	1.07
100	0.010	49,638	175.86	1.14
200	0.005	54,031	177.05	1.18
500	0.002	60,445	178.58	1.10
N/A	N/A	80,000	**182.00**	1.10

Reach Chehalis 4				
Index Cross-Section (RM) 68.67				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	451	149.90	0.00
2	0.500	18,743	166.90	0.75
5	0.200	27,075	169.82	0.75
10	0.100	31,511	171.14	0.76
25	0.040	40,364	173.22	0.78
50	0.020	47,113	174.50	0.81
100	0.010	52,678	175.59	0.84
200	0.005	59,865	176.81	0.87
500	0.002	69,541	178.36	0.90
N/A	N/A	90,000	**181.50**	0.90

Reach Chehalis 5				
Index Cross-Section (RM) 67.29				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	471	149.90	0.00
2	0.500	18,718	165.45	0.78
5	0.200	27,071	168.36	0.72
10	0.100	31,396	169.59	0.70
25	0.040	40,512	171.42	0.68
50	0.020	47,289	172.47	0.68
100	0.010	53,343	173.40	0.69
200	0.005	61,636	174.40	0.74
500	0.002	72,201	175.72	0.86
N/A	N/A	95,000	**178.50**	0.86

Reach Chehalis 6				
Index Cross-Section (RM) 66.30				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	599	149.80	0.00
2	0.500	24,251	161.89	0.60
5	0.200	34,728	164.10	0.68
10	0.100	41,029	165.28	0.71
25	0.040	52,740	167.03	0.72
50	0.020	61,363	167.96	0.71
100	0.010	70,006	168.81	0.70
200	0.005	80,817	169.81	0.70
500	0.002	96,788	171.06	0.77
N/A	N/A	120,000	**173.00**	0.77

Reach Chehalis 7				
Index Cross-Section (RM) 65.20				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	323	143.75	0.00
2	0.500	24,260	157.97	0.66
5	0.200	34,717	160.67	0.63
10	0.100	41,006	162.01	0.61
25	0.040	52,754	163.70	0.59
50	0.020	61,399	164.67	0.57
100	0.010	70,026	165.51	0.56
200	0.005	80,800	166.50	0.55
500	0.002	96,802	167.77	0.55
N/A	N/A	120,000	**169.50**	0.55

Reach Skookumchuck 1				
Index Cross-Section (RM) 10.56				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	1,263	234.59	0.39
3.1	0.323	4,129	238.59	0.39
6.1	0.164	5,750	239.82	0.40
12.7	0.079	7,147	240.68	0.40
34	0.029	9,238	241.74	0.41
50	0.020	10,258	242.17	0.42
88	0.011	11,428	242.60	0.43
143	0.007	12,500	242.97	0.44
320	0.0031	14,331	243.60	0.46
482	0.0021	15,750	244.04	0.49
N/A	N/A	25,000	**247.00**	0.49

Reach Skookumchuck 2				
Index Cross-Section (RM) 5.08				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	1,319	195.60	0.39
3.1	0.323	4,191	200.89	0.39
6.1	0.164	5,797	202.01	0.36
12.7	0.079	7,355	202.89	0.33
34	0.029	9,393	203.62	0.27
50	0.020	10,561	203.92	0.24
88	0.011	11,804	204.19	0.21
143	0.007	12,940	204.43	0.20
320	0.0031	14,867	204.81	0.20
482	0.0021	16,137	205.04	0.23
N/A	N/A	25,000	**206.70**	0.23

Reach Skookumchuck 3				
Index Cross-Section (RM) 2.415				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	2,039	180.55	0.40
3.1	0.323	5,369	184.00	0.40
6.1	0.164	7,423	185.19	0.37
12.7	0.079	9,322	185.89	0.35
34	0.029	12,147	186.65	0.32
50	0.020	13,792	187.06	0.30
88	0.011	16,183	187.56	0.28
143	0.007	17,885	187.79	0.26
320	0.0031	21,158	188.07	0.24
N/A	N/A	40,000	**189.50**	0.24

Reach Skookumchuck 4				
Index Cross-Section (RM) 0.98				
Return Period (years)	Probability of Occurrence	Discharge (cfs)	Stage (ft)	Standard Deviation of Error (ft)
N/A	N/A	2,141	165.82	0.68
3.1	0.323	5,508	171.31	0.68
6.1	0.164	7,623	173.77	0.48
12.7	0.079	9,553	174.36	0.37
34	0.029	12,381	175.21	0.32
50	0.020	14,091	175.84	0.33
88	0.011	16,554	176.39	0.39
143	0.007	18,124	176.90	0.44
320	0.0031	21,195	177.69	0.56
N/A	N/A	40,000	**181.00**	0.56

In addition to the 11 damage reaches incorporated into the UNET hydraulic model, 25 hydraulic storage areas were also modeled. Each storage area was linked in the flood damage assessment model to a single index cross section on either the Chehalis or Skookumchuck Rivers. Table 3-6 lists the modeled storage areas and their linkages.

TABLE 3-6 UNET STORAGE AREAS AND LINKS TO INDEX CROSS-SECTIONS FOR THE HEC-FDA ANALYSIS

Storage Area Number [1]	River cross-section that storage area is hydraulically linked to [2]	Associated Economics Reach [3]	Associated Index Cross-Section [3]
102	Newaukum RM 0.08	Chehalis Econ. Reach 1	Chehalis RM 74.02
101	Newaukum RM 0.08	Chehalis Econ. Reach 1	Chehalis RM 74.02
100	Chehalis RM 76.70	Chehalis Econ. Reach 1	Chehalis RM 74.02
301	Dillenbaugh RM 0.623	Chehalis Econ. Reach 1	Chehalis RM 74.02
302	Dillenbaugh RM 0.623	Chehalis Econ. Reach 1	Chehalis RM 74.02
303	Chehalis RM 74.57	Chehalis Econ. Reach 1	Chehalis RM 74.02
2	Chehalis RM 72.80	Chehalis Econ. Reach 2	Chehalis RM 72.80
3	Salzer RM 1.56	Chehalis Econ. Reach 4	Chehalis RM 68.67
4	Salzer RM 1.28	Chehalis Econ. Reach 4	Chehalis RM 68.67
5	Chehalis RM 68.05	Chehalis Econ. Reach 4	Chehalis RM 68.67
501	Chehalis RM 68.67	Chehalis Econ. Reach 4	Chehalis RM 68.67
601	Skookumchuck RM 2.99	Skookumchuck Econ. Reach 3	Skookumchuck RM 2.415
602	Skookumchuck RM 2.415	Skookumchuck Econ. Reach 3	Skookumchuck RM 2.415
603	China Creek - N/A [4]	Not included in stage-damage function	N/A
604	China Creek - N/A [4]	Not included in stage-damage function	N/A
605	China Creek - N/A [4]	Not included in stage-damage function	N/A
606	Skookumchuck RM 2.00	Skookumchuck Econ. Reach 3	Skookumchuck RM 2.415
608	China Creek - N/A [4]	Not included in stage-damage function	N/A
609	Skookumchuck RM 0.49	Skookumchuck Econ. Reach 4	Skookumchuck RM 0.98
610	Chehalis RM 67.36	Chehalis Econ. Reach 5	Chehalis RM 67.29
701	Skookumchuck RM 5.08	Skookumchuck Econ. Reach 2	Skookumchuck RM 5.08
702	Skookumchuck RM 5.08	Skookumchuck Econ. Reach 2	Skookumchuck RM 5.08
703	Skookumchuck RM 5.08	Skookumchuck Econ. Reach 2	Skookumchuck RM 5.08
704	Skookumchuck RM 5.08	Skookumchuck Econ. Reach 2	Skookumchuck RM 5.08
705	Skookumchuck RM 2.00	Skookumchuck Econ. Reach 3	Skookumchuck RM 2.415

1 - Storage Area number as related to the Chehalis UNET model and as delineated on the 1"=400' scale maps.

2 - Stream and river mile most closely associated with overflow to storage area.

3 - Economics reach and associated index cross-section that should be used to link the storage area to hydrologic (discharge-probability) and hydraulic (stage-discharge) information.

4 - Storage area is mostly flooded from China Creek (China Creek is not modeled hydraulically in the UNET model).

Table 3-7 provides the non-damaging elevation (bank-height) used for calculating damages in each study reach. These values are used in the analysis to identify the point at which water leaves the channel and damages may start to accrue.

TABLE 3-7 NON-DAMAGING ELEVATIONS BY REACH

Chehalis River Index Cross-Sections

Reach	**Index Cross-Section**	**Estimated zero-damage elevation at Index Cross-Section**
	(RM)	(feet - msl)
Chehalis 1	74.02	172.5
Chehalis 2	72.80	172.3
Chehalis 3	70.30	169.2
Chehalis 4	68.67	166.2
Chehalis 5	67.29	168.0
Chehalis 6	66.30	164.0
Chehalis 7	65.20	160.0

Bank elevations are in feet (msl) as defined in the UNET model
Estimated zero-damage stage at index cross-section (to be used for stage-damage evaluation)
All of the elevations given in these tables are referenced to the NGVD 1929 vertical datum

Skookumchuck River Index Cross-Sections

Reach	**Index Cross-Section**	**Estimated zero-damage elevation at Index Cross-Section**
	(RM)	(feet - msl)
Skookumchuck 1	10.56	240.6
Skookumchuck 2	5.08	201.5
Skookumchuck 3	2.415	184.5
Skookumchuck 4	0.98	173.0

Bank elevations are in feet (msl) as defined in the UNET model
Estimated zero-damage stage at index cross-section (to be used for stage-damage evaluation)
All of the elevations given in these tables are referenced to the NGVD 1929 vertical datum

Table 3-8 provides the frequency distribution for the annual peak flows for both the Chehalis River and the Skookumchuck River under the without project condition. The uncertainty associated with these values is computed based on the equivalent length of record, which is 70 years on the Chehalis River and 49 years on the Skookumchuck River.

TABLE 3-8 WITHOUT-PROJECT DISCHARGE-PROBABILITY FUNCTION STATISTICS FOR HEC-FDA

Chehalis River Reaches							
Reach	**Chehalis 1**	**Chehalis 2**	**Chehalis 3**	**Chehalis 4**	**Chehalis 5**	**Chehalis 6**	**Chehalis 7**
Index Cross-Section (RM)	**74.02**	**72.80**	**70.30**	**68.67**	**67.29**	**66.30**	**65.20**
Equivalent Record Length (years)	**70**	**70**	**70**	**70**	**70**	**70**	**70**
Exceedance Probability	**Discharge (cfs)**	**Discharge (cfs)**	**Discharge (cfs)**	**Discharge (cfs)**	**Discharge (cfs)**	**Discharge (cfs)**	**Discharge (cfs)**
0.999	14,516	10,455	5,079	8,549	8,448	11,683	11,688
0.500	21,637	20,231	18,648	18,743	18,718	24,251	24,260
0.200	28,285	27,181	26,573	25,951	26,030	33,620	33,632
0.100	33,715	32,444	31,978	31,429	31,606	40,892	40,906
0.040	41,835	39,889	38,958	39,202	39,539	51,392	51,408
0.020	48,878	46,043	44,257	45,645	46,132	60,233	60,251
0.010	56,851	52,747	49,638	52,678	53,343	70,006	70,026
0.005	65,898	60,078	55,132	60,384	61,259	80,847	80,869
0.002	79,781	70,871	62,613	71,750	72,958	97,060	97,085
0.001	91,971	79,974	68,458	81,352	82,862	110,942	110,970

Skookumchuck River Reaches				
Reach	**Skookumchuck 1**	**Skookumchuck 2**	**Skookumchuck 3**	**Skookumchuck 4**
Index Cross-Section (RM)	**10.56**	**5.08**	**2.42**	**0.98**
Equivalent Record Length (years)	**49**	**49**	**49**	**49**
Exceedance Probability	**Discharge (cfs)**	**Discharge (cfs)**	**Discharge (cfs)**	**Discharge (cfs)**
0.999	573	549	976	1,029
0.500	3,200	3,200	4,050	4,200
0.200	5,109	5,170	6,508	6,713
0.100	6,525	6,645	8,471	8,712
0.040	8,470	8,683	11,358	11,642
0.020	10,025	10,321	13,819	14,133
0.010	11,666	12,057	16,562	16,903
0.005	13,402	13,900	19,620	19,987
0.002	15,856	16,515	24,212	24,606
0.001	17,841	18,638	28,152	28,561

3.6 Expected Without-Project Flood Damages

3.6.1 Residential Structure and Content Damages

In the study area there were approximately 4,000 residential units counted from base maps prepared by the Corps of Engineers, with a depreciated structural value of approximately $383,517,000[4], yielding an average residential unit cost of $97,700. Residential flood inundation damages to structures referenced to the Chehalis River by event are shown in Table 3-9.

TABLE 3-9 CHEHALIS RIVER RESIDENTIAL INUNDATION DAMAGE BY EVENT

Flood Event	Structure	Content
25-year	8,487,000	4,949,000
50-year	14,072,000	8,117,000
100-year	19,552,000	11,187,000
500-year	50,953,000	28,297,000

Residential flood inundation damages to structures referenced to the Skookumchuck River by event are shown in Table 3-10.

TABLE 3-10 SKOOKUMCHUCK RIVER RESIDENTIAL INUNDATION DAMAGE BY EVENT

Flood Event	Structure	Content
34-year	4,709,000	2,826,000
50-year	6,362,000	3,785,000
88-year	9,086,000	5,349,000
143-year	12,753,000	7,479,000
320-year	18,783,000	10,853,000

3.6.2 Residential Clean-up Cost

Flooding not only causes damage to structures and contents but floodwaters present significant cleanup costs in their aftermath. Floodwaters leave debris, sediment and the dangers of diseases and mycotoxins throughout flooded structures. The cleaning of these structures is a necessary

[4] All dollar values are expressed at 2002 price level.

post-flood activity. Clean-up costs for the extraction of floodwaters, dry-out, and decontamination range from $1 to $4.75 per square foot, with a mean cost of $3.65 and standard deviation of $0.94 based on prior studies. Residential clean-up costs by location are shown in Table 3-11 and Table 3-12.

TABLE 3-11 RESIDENTIAL CLEAN-UP COSTS CHEHALIS RIVER BY EVENT

Flood Event	Cleanup Costs
25-year	2,976,000
50-year	4,377,000
100-year	5,510,000
500-year	9,481,000

TABLE 3-12 RESIDENTIAL CLEAN-UP COSTS SKOOKUMCHUCK RIVER BY EVENT

Flood Event	Cleanup Costs
34-year	2,139,000
50-year	2,672,000
88-year	3,454,000
143-year	4,657,000
320-year	5,853,000

3.6.3 Emergency Costs

ER 1105-2-100 states, “Flood damages are classified as physical damages or losses, income losses, and emergency costs.” The ER then defines emergency costs as “those expenses resulting from a flood what would not otherwise be incurred…” The ER further requires that emergency costs should not be estimated by applying an arbitrary percentage to the physical damage estimates. As with all flood damage estimates and especially in the case of emergency costs, the potentials to double count damages are a distinct possibility and must be guarded against.

FEMA provides grants to assist individuals and families to find suitable housing when they are displaced in cases of Federally declared disasters. This assistance being directly attributable to the disaster and being an expenditure that would not be undertaken except for the disaster falls clearly under the emergency costs guidance of ER 1105-2-100. Therefore, funds expended by FEMA for Temporary Rental Assistance or Funds for Minor Emergency Home Repairs (TRA) in the event of flooding are NED flood damages.

Complying with ER 1105-2-100, an Internet database search of FEMA disaster reports for flood and storm damage was performed. In these studies, the average per claim expenditure by FEMA for TRA ranged from $583 to $2,034 with an overall average expenditure of $1,537 per claim. The standard deviation of the average per claim expenditures is $411. For risk-based modeling purposes it is assumed that TRA per claim expenditure is normally distributed with a mean of $1,537 and a standard deviation of $411.

FEMA will reimburse local and state governments and certain nonprofits up to 75 percent of eligible disaster response costs through the public assistance program. It includes all or parts of the following:

- Debris removal
- Emergency protective measures
- Road systems and bridges
- Water control facilities
- Public buildings and contents
- Public utilities
- Parks, recreational and other activities of a governmental nature

These costs, as well as the 25 percent contribution by local and state governments and the nonprofits, are eligible NED emergency costs under ER 1105-2-100. Again, care must be taken to make sure double counting does not occur between public assistance expenditures and structural or other damage categories.

Total Public Assistance (PA) expenditures were found to be 3.01 times the expenditures on TRA. On an individual disaster basis, PA expenditures range from zero to an unknown factor based on the FEMA reports, with the highest reported factor of 9.45. Applying the four standard deviation rule, common to other HEC-FDA variance protocols, the risked-based function of PA is a mean damage of 3.01 times the individual TRA expenditure with a normal deviate of a multiple of 2.36 bounded by zero damage.

Emergency costs (temporary relocation and public assistance expenditures) by flood event and river are shown in Table 3-13 and Table 3-14.

TABLE 3-13 EMERGENCY COSTS – CHEHALIS RIVER

Flood Event	Temporary Relocation Assistance	Public Assistance
25-year	419,000	1,456,000
50-year	675,000	2,345,000
100-year	924,000	3,212,000
500-year	2,109,000	7,327,000

TABLE 3-14 EMERGENCY COSTS – SKOOKUMCHUCK RIVER

Flood Event	Temporary Relocation Assistance	Public Assistance
34-year	249,000	864,000
50-year	335,000	1,161,000
88-year	472,000	1,641,000
143-year	654,000	2,274,000
320-year	943,000	3,276,000

3.6.4 Commercial And Industrial Inundation Damage

Within the study area there are approximately 300 commercial and industrial properties with a total floor space of approximately 2,507,000 square feet. The total nominal depreciated structure value of these properties is $146,730,000 with a total content value of $189,575,000. The average square footage cost of these structures is $46. Overall content-to-structure value ratio for these structures is 129.2%. Flood inundation damages to these structures by river and event are shown in Table 3-15 and Table 3-16.

TABLE 3-15 CHEHALIS COMMERCIAL AND INDUSTRIAL INUNDATION DAMAGE BY EVENT

Flood Event	Structure Damage	Content Damage
25-year	1,685,000	1,709,000
50-year	11,495,000	14,620,000
100-year	14,735,000	20,116,000
500-year	25,153,000	39,367,000

TABLE 3-16 SKOOKUMCHUCK COMMERCIAL/INDUSTRIAL INUNDATION DAMAGE BY EVENT

Flood Event	Structure Damage	Content Damage
34-year	2,481,000	2,122,000
50-year	2,927,000	2,602,000
88-year	4,317,000	4,020,000
143-year	5,007,000	5,345,000
320-year	6,114,000	7,204,000

3.6.5 Commercial and Industrial Clean-up Costs

Nonresidential clean-up costs are limited to public, commercial, and retail structures normally expected to engage with the public, e.g., restaurants, retail stores, office structures and other such businesses. Clean-up costs are not anticipated to occur with light industrial or other non-public commercial enterprises. Clean-up costs for commercial and industrial structures are presented in Table 3-17 and Table 3-18.

TABLE 3-17 CHEHALIS NONRESIDENTIAL CLEAN-UP COSTS BY EVENT

Flood Event	Clean-up Costs
25-year	310,000
50-year	2,905,000
100-year	3,768,000
500-year	5,609,000

TABLE 3-18 SKOOKUMCHUCK NONRESIDENTIAL CLEAN-UP COSTS BY EVENT

Flood Event	Clean-up Costs
34-year	461,000
50-year	481,000
88-year	643,000
143-year	1,004,000
320-year	1,022,000

3.6.6 Public Inundation Damage

The floodplain survey identified 138 public structures whose locations are shown in Table 5 - Public Inventory. These structures cover an area of approximately 1,109,500 square feet and have a depreciated structural value of $69,040,000 or approximately $68 per square foot. Each public structure's content value was determined individually based its function in coordination with past Corps evaluations of similar functions. The total for all public structures equals $64,798,000, which yields an average content-to-structure ratio of 94%. Flood inundation damages to these structures by river and event are shown in Tables 3-19 and 3-20.

TABLE 3-19 CHEHALIS PUBLIC STRUCTURE INUNDATION DAMAGE BY EVENT

Flood Event	Structure Damage	Content Damage
25-year	537,000	359,000
50-year	3,965,000	3,267,000
100-year	4,978,000	4,050,000
500-year	10,239,000	9,836,000

TABLE 3-20 SKOOKUMCHUCK PUBLIC STRUCTURE INUNDATION DAMAGE BY EVENT

Flood Event	Structure Damage	Content Damage
34-year	1,188,000	1,364,000
50-year	1,621,000	1,684,000
88-year	1,767,000	1,975,000
143-year	2,989,000	2,837,000
320-year	3,453,000	3,788,000

Clean-up costs for public structures are presented in Table 3-21 and Table 3-22.

TABLE 3-21 CHEHALIS PUBLIC STRUCTURE CLEAN-UP COSTS BY EVENT

Flood Event	Clean-up Costs
25-year	16,000
50-year	379,000
100-year	422,000
500-year	1,398,000

TABLE 3-22 SKOOKUMCHUCK PUBLIC STRUCTURE CLEAN-UP BY EVENT

Flood Event	Clean-up Costs
34-year	132,000
50-year	242,000
88-year	258,000
143-year	397,000
320-year	543,000

3.6.7 Inundation Damage Summary

Table 3-23 on the following page presents a summary of the previously discussed damages.

TABLE 3-23 STRUCTURAL DAMAGE SUMMARY

Chehalis River

Flood Event	Residential			Commercial			Public					
	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	TOTAL
25-year	8,487,000	4,949,000	2,976,000	1,685,000	1,709,000	310,000	537,000	359,000	16,000	419,000	1,456,000	22,903,000
50-year	14,072,000	8,117,000	4,377,000	11,495,000	14,620,000	2,905,000	3,965,000	3,267,000	379,000	675,000	2,345,000	66,217,000
100-year	19,552,000	11,187,000	5,510,000	14,735,000	20,116,000	3,768,000	4,978,000	4,050,000	422,000	924,000	3,212,000	88,454,000
500-year	50,953,000	28,297,000	9,481,000	25,153,000	39,367,000	5,609,000	10,239,000	9,836,000	1,398,000	2,109,000	7,327,000	189,769,000

Skookumchuck River

Flood Event	Residential			Commercial			Public					
	Structure	Content	Cleanup	Structure	Content	Cleanup	Structure	Content	Cleanup	TRA	PA	Total
34-year	4,709,000	2,826,000	2,139,000	2,481,000	2,122,000	461,000	1,188,000	1,364,000	132,000	249,000	864,000	18,535,000
50-year	6,362,000	3,785,000	2,672,000	2,927,000	2,602,000	481,000	1,621,000	1,684,000	242,000	335,000	1,161,000	23,872,000
88-year	9,086,000	5,349,000	3,454,000	4,317,000	4,020,000	643,000	1,767,000	1,975,000	258,000	472,000	1,641,000	32,982,000
143-year	12,753,000	7,479,000	4,657,000	5,007,000	5,345,000	1,004,000	2,989,000	2,837,000	397,000	654,000	2,274,000	45,396,000
320-year	18,783,000	10,853,000	5,853,000	6,114,000	7,204,000	1,022,000	3,453,000	3,788,000	543,000	943,000	3,276,000	61,832,000

3.6.8 Residential, Nonresidential, and Public HEC-FDA Model Results

Stage-damage functions were developed for each damage category and were combined with the hydrology and hydraulic information into the HEC-FDA model for computation of the expected annual damages with uncertainty. The results of the HEC-FDA model are shown in Table 3-25 – Expected Annual Damages by Reach. Total expected annual damage on the Chehalis River is $6,590,730 and $2,254,190 for the Skookumchuck River. The relative damage by category is shown below in Table 3-24 - Expected Annual Damage by Category for each river.

TABLE 3-24 EXPECTED ANNUAL DAMAGE BY CATEGORY

Category	Chehalis River		Skookumchuck River	
	$ Damage	Percentage	$ Damage	Percentage
Residential				
Structure	1,789,290	27.15%	663,700	29.44%
Content	1,036,310	15.72%	394,210	17.49%
Clean-up	588,290	8.93%	278,600	12.36%
Nonresidential				
Structure	1,002,610	15.21%	352,340	15.63%
Content	1,119,860	16.99%	311,300	13.81%
Clean-up	239,120	3.63%	62,240	2.76%
Public				
Structure	229,080	3.48%	22,800	1.01%
Content	189,360	2.87%	15,290	0.68%
Clean-up	24,490	0.37%	4,270	0.19%
TRA	83,250	1.26%	33,380	1.48%
PA	289,070	4.39%	116,060	5.15%
TOTAL*	6,590,730	100.00%	2,254,190	100.00%

**Total may not add due to rounding*

TABLE 3-25 EXPECTED ANNUAL DAMAGES BY REACH

Expected Annual Damage for the Without Project Condition													
Stream	**Reach**	**Damage Categories (Damage in $1,000's)**											
		Commercial Cleanup	Commercial Contents	Commercial Structures	Public Assistance	Residential Cleanup	Residential Contents	Residential Structures	Temporary Relocation Assistance	Public Cleanup	Public Contents	Public Structures	Total
Chehalis	Reach 7b	0.02	10.05	11.27	64.22	92.98	240.04	427.35	18.50	2.07	2.11	9.12	877.73
	Reach 7	0.00	0.00	0.00	1.68	4.96	5.86	9.74	0.48	5.26	19.20	23.41	70.59
	Reach 6	1.54	6.57	8.14	21.40	53.10	73.95	124.28	6.13	1.22	6.30	7.95	310.58
	Reach 5	0.00	0.00	30.19	2.72	7.19	9.77	16.37	0.80	0.11	2.06	2.44	71.65
	S610B	13.45	36.81	64.72	27.25	60.32	98.64	169.26	7.82	5.58	59.19	59.67	602.71
	Reach 4	3.58	37.07	40.78	25.01	55.65	92.68	159.20	7.26	1.80	11.65	13.27	447.95
	S3	13.01	67.14	62.87	3.29	4.95	14.40	26.13	0.95	7.93	65.13	93.83	359.63
	S4	61.81	344.33	216.17	1.09	1.66	4.06	7.21	0.31	0.00	0.00	0.00	636.64
	S5	1.43	13.83	8.14	10.73	13.08	45.47	82.75	3.09	0.11	0.95	0.80	180.38
	Reach 3	5.94	28.80	16.96	14.34	27.62	50.72	87.86	4.11	0.00	0.00	0.00	236.35
	Reach 2	25.73	54.28	96.08	23.26	47.63	79.87	137.11	6.62	0.00	0.00	0.00	470.58
	S2	26.45	195.95	125.52	2.76	3.87	11.88	21.51	0.80	0.33	22.12	16.35	427.54
	Reach 1	1.71	19.84	31.67	74.64	176.26	250.69	421.91	21.60	0.07	0.65	2.23	1001.27
	S101	0.00	0.00	0.00	0.58	1.04	2.20	3.70	0.10	0.00	0.00	0.00	7.62
	S102	0.00	0.00	0.00	2.09	4.13	7.69	13.37	0.65	0.00	0.00	0.00	27.93
	S302	84.44	305.20	290.11	10.05	27.41	34.69	57.58	2.86	0.00	0.00	0.00	812.34
	S303	0.00	0.00	0.00	3.95	6.45	13.68	23.97	1.15	0.00	0.00	0.00	49.20
Total Chehalis		*239.12*	*1119.86*	*1002.61*	*289.07*	*588.29*	*1036.31*	*1789.29*	*83.25*	*24.49*	*189.36*	*229.08*	*6590.73*
Skookumchuck	Reach 4	39.36	150.35	219.73	22.24	54.90	83.13	141.74	6.40	1.80	7.62	9.11	736.38
	SK-609	0.00	0.00	0.00	10.67	20.97	38.10	66.08	3.09	0.00	0.00	0.00	138.91
	Reach 3	18.44	143.21	113.68	43.71	111.39	146.07	243.32	12.52	0.00	0.00	0.00	832.34
	SK-602	0.35	1.96	2.25	1.93	5.90	6.37	10.29	0.56	0.13	0.48	0.65	30.87
	SK-606	0.01	0.02	0.02	1.32	3.99	4.42	7.15	0.38	1.10	4.81	6.65	29.87
	SK-705	0.00	3.19	3.40	1.19	4.85	4.32	6.78	0.35	0.00	0.00	0.00	24.08
	Reach 2	0.00	0.00	0.00	8.34	17.39	25.88	43.59	2.38	0.00	0.00	0.00	97.58
	SK-701	0.00	0.00	0.00	0.74	1.75	2.12	3.48	0.20	0.00	0.00	0.00	8.29
	SK-702	0.00	0.00	0.00	14.33	28.25	45.98	78.45	4.16	0.00	0.00	0.00	171.17
	SK-703	0.17	1.42	2.15	3.37	14.32	12.56	19.58	1.01	0.00	0.00	0.00	54.58
	SK-704	0.00	0.00	0.00	0.44	1.69	1.50	2.33	0.09	0.00	0.00	0.01	6.06
	Reach 1	3.92	11.14	11.10	7.80	13.21	23.76	40.91	2.24	1.24	2.38	6.38	124.08
Total Skookumchuck		*62.24*	*311.30*	*352.34*	*116.06*	*278.60*	*394.21*	*663.70*	*33.38*	*4.27*	*15.29*	*22.80*	*2254.19*
TOTAL ALL STREAMS		**301.36**	**1431.16**	**1354.95**	**405.13**	**866.89**	**1430.52**	**2452.99**	**116.63**	**28.76**	**204.65**	**251.88**	**8844.92**

3.6.9 Agricultural Flood Damages

The Planning Guidance Notebook of the USACE (ER 1105-2-100) has specific rules on the treatment of agricultural crops. Agricultural crops are divided into two categories. The first is basic crops and the second is other crops. The guidance indicates that the loss in income is only applicable to basic crops and that damages to other crops are limited to the variable costs per USACE, IWR Report 87-R-10. These conventions are the basis of the current agricultural analysis.

With no change in cropping patterns anticipated, benefits are restricted to damage reduction benefits. Damage reduction benefits are the increases in net income due to the plan, as measured by farm budget analysis. These income increases may result from increased crop yields and decreased production costs.

The study area contains approximately 2,200 acres of agricultural lands that are subject to flooding. Three crops are listed as the principal for the study area, as shown in Table 3-26.

TABLE 3-26 LEWIS COUNTY CROP HARVESTS – 1996

Crop	Acres	Percentage
Hay	1,320	60%
Green Peas – Process	550	15%
Sweet Corn – Process	330	25%
Total	2,200	100%

Source: Cooperative Extension Office – Lewis County

Agricultural acreage for the study is treated as having a composite crop based on the above three crops. The use of a composite crop was required because no formal survey of agricultural production by location was conducted. Agricultural production acreage and locations were ascertained through the use of an overlay of flood plain boundaries on aerial photography of agricultural production acreage. Farm budgets were obtained from the Cooperative Extension, Washington State University and damages computed based on the monthly probability of flood occurrence. Through farm budget analysis the per-acre damage has been determined at the following values for the crops of the study area (Table 3-27).

TABLE 3-27 PER ACRE CROP DAMAGE

Crop Type	Per Acre Damage	Weight	Weighted Loss
Hay	$220.48	60%	$132
Corn	$52.77	25%	$13
Peas	$61.60	15%	$9
Total per acre loss			$155

The requirement to restore agricultural land after flood inundation necessitates the reworking of fields at twice the level of normal land preparation and the application of additional cycles of fertilizer, weed control, and pest control, based upon consultation with the Lewis County Farm Advisor. The estimated net cost for agricultural land restoration on a per acre basis is presented in Table 3-28.

TABLE 3-28 PER ACRE FIELD CROPLAND RESTORATION COSTS

Operation	$ Cost/per Acre
Disc (4 times)	60.00
Subsoil	9.00
Chisel Field (2 times)	15.00
Landplane (2 times)	24.00
Fertilize	64.00
Weed Control	45.00
Pest Control	26.00
Total	$243.00

In addition to restoration costs, it is assumed that post-flood clean-up of debris and other matter will cost $20 per acre for all agricultural land.

3.6.10 Summary of Agricultural Flood Damages

Agricultural damages by flood event are shown in Table 39.

TABLE 3-29 AGRICULTURAL DAMAGES BY FLOOD EVENT

Flood Event	Crop Damage	Land Restoration	Clean-up	Total
6-year	52,000	82,000	6,000	140,000
10-year	227,000	356,000	29,000	612,000
100-year	341,000	534,000	44,000	919,000
500-year	341,000	534,000	44,000	919,000

Expected annual agricultural damages were calculated using HEC-EAD. The results of the HEC-EAD model for agricultural damages are shown in Table 3-30.

TABLE 3-30 EXPECTED ANNUAL AGRICULTURAL DAMAGE

Category	Expected Annual Damage
Crop Damage	42,930
Land Restoration Costs	67,420
Clean-up Costs	5,500
Total	115,850

3.6.11 Transportation Related Damages

Chehalis River flooding presents a serious threat to interstate commerce. Past floods have necessitated the closure of U.S. Interstate 5 to vehicle traffic, as well as the closures of two major railroad lines (Burlington Northern Santa Fe and Union Pacific Railroads). The costs associated with travel delays, diversion costs, and clean-up costs are valid project concerns on a National Economic Development (NED) basis. The following sections explore these transportation related damages.

Mapping of the floodplains indicates that Interstate 5 will be subject to closure from floods. I-5 will be closed between Centralia and Chehalis. This mapping also indicates that a diversion around the floodplain will be required. This diversion will be quite lengthy, approximately 101 miles. The diversion, going southbound, involves leaving I-5 at its junction with SR-507 traveling northeast to Yelm, transitioning to SR-702 east and proceeding to SR-7. Proceeding southward on SR-7 for approximately 35 miles to Morton where a connection to U.S.-12 westbound is taken to return to I-5. Northbound traffic would reverse the route.

The estimate of the traffic count involved in the diversion is taken from the State of Washington Department of Transportation's Trips System for 2000. Average total daily through traffic between state route milepost 81.21 (before ramp SR 507) and milepost 68.94 (after ramp SR-12) Bow Hill Rd. is estimated at 51,000. In the immediate vicinity of the cities of Chehalis and Centralia average daily volume reaches approximately 62,000, but this added traffic is assumed to not leave the area. The affected daily traffic for the analysis is a base flow traffic rate of 51,000. Further, the analysis employs the Trips System indication that 12 percent of the traffic is truck as measured by the Bow Hill Rd. indicator.

The analysis of transportation delays and costs was carried forward by employing the procedure in ER 1105-2-100, Appendix D and as shown in Table D-4: Value of Time (VOT) Saved by Trip Length and Purpose of that appendix, with a measure of median household income for Lewis County of $32,557 (1997 U.S. Bureau of the Census). A per vehicle passenger rate of 1.15 is assumed for the analysis. The diversion is estimated to take 3.16 hours, assuming a 32 mph diversion speed. Mileage rates are further assumed to be 34.5 and 48 cents for cars and truck, respectfully. The above factors yield the following transportation related damages (Table 3-31).

TABLE 3-31 INTERSTATE 5 DAILY TRANSPORTATION DELAY COSTS WHEN FLOODED

								Daily Costs		
	Value of Time $/hr	**Occupancy Factor**	**Occ. Weighted VOT**	**Time Costs**	**Diversion Mileage Cost**	**Total Cost per Vehicle**	**Vehicle Units**	**Time**	**Mileage**	**Total**
Cars	8.42	1.15	9.68	$30.57	$34.85	$65.41	44880	$1,371,783	$1,563,844	$2,935,627
Trucks	8.42	1	8.42	$26.58	$48.48	$75.06	6120	$162,662	$296,698	$459,360
TOTAL								$1,534,445	$1,860,541	$3,394,986

Transportation delay costs due to flood impacts are shown in the table below based on estimated closure durations for flooding and cleanup for Chehalis-Centralia area.

TABLE 3-32 INTERSTATE 5 DAMAGES BY FLOOD EVENT

Flood Event	I-5 Closure in Days	Total Cost
25	0	$0
50	4	$13,579,945
100	4.5	$15,277,438
200	5	$16,974,931
500	6	$20,369,917

Applying these flood related values to the HEC-EAD model yields an estimate of equivalent annual damage of $476,300. Based upon a planned elevation of I-5 in the without-project condition, traffic delays were assumed to occur only through 2012 (estimated completion of elevation). Average annual traffic delay damages through 2012 amount to $129,100.

3.6.12 Avoided Cost of Interstate 5 Widening

The project purpose of the Centralia, Washington Flood Damage Reduction PED Study is to reduce flood hazards and flood damage costs in the project area to the maximum extent practicable. In addition to providing flood protection to thousands of homes and hundreds of businesses, the project will also reduce inundation to Interstate Highway 5 (I-5) in the Chehalis-Centralia area. This highway has been particularly susceptible to inundation in the project area historically, and has been shut down twice in the last 10-years with floodwater up to 8 feet in depth over the roadway (closed for 4-days in 1996, and 1 day in 1990).

Due to safety issues, and the tremendous economic impacts associated with I-5 closures, the Washington State Department of Transportation (WSDOT) is on record as stating that I-5 will require raising to above the 100-year flood elevation at the same time as other Federally mandated widening and upgrading is accomplished. The incremental costs of raising the freeway under the *without project* condition has been estimated at $44 million. The plan for I-5 indicates that implementation would take place after the base year of any of the alternatives and would be finished in 2012. Discounting this future expenditure yields a current base year value of $32,686,200. Amortization of this avoided cost yields average annual savings of $2,110,000. If the Recommended Plan turns out to provide at least 100-year protection to this section of I-5, the incremental costs of raising the freeway would not need to be expended. Under this scenario, the avoided cost can be included as an NED benefit (though it is not included in the accounting of “damages”).

3.6.13 Rail Freight Flood Impacts

The basis for the examination of NED costs from rail disruptions is the Pharos Corporation’s “Chehalis River Flood Reduction Project” study of 2001 for Lewis County (Appendix D). The study reports that the Burlington Northern Santa Fe Railway (BNSF) owns and operates the rail line running north and south within the Chehalis flood plain. This double main-line track parallels Interstate 5 within the flood plain and continues south to Eugene, OR, where it connects with the Union Pacific Railroad. BNSF traffic typically ranges from 30 to 40 trains per day, and are primarily composed of grain for export; forest products imported from Canada; and domestic shipments of metals and minerals, coal, chemicals, automobiles and consumer goods.

The second major rail service connected to the study area is the Union Pacific Railroad (UPRR). Although UPRR lines do not run directly within the flood plain, the UPRR operates its own trains over the BNSF's track in the Chehalis corridor to access and route shipments to many of their western Washington rail customers via trackage rights. The number of UPRR trains utilizing the Chehalis corridor amounts to 18 to 20 trains per day.

Based on annual reports published by BNSF and UPRR and assuming a per rail car carrying weight of 268,000 pounds, the estimated daily rail car transit rate is 1,230 in the Chehalis corridor. In the event of a prolonged rail outage, these rail lines may be forced to reroute traffic via routes in either Pasco or Spokane, WA. The shortest alternate route bypassing the Chehalis flood plain would increase trip mileage by 350 miles. BNSF estimates that the average mileage payout for equipment rent/car ownership at approximately $0.40 per mile. Given the mileage increase of the shortest alternate route, the additional cost per railcar diverted equals $140.00 or $172,200 per day for all railcars being diverted.

Furthermore, depending on the alternate line's available capacity, the rerouted cars would likely be subject to a minimum of 48 hours of extended transit time for the additional 350-mile trip. Estimating from the 1999 primary carriers annual reports, the approximate average daily equipment expense per railcar is $23.30. On an estimated daily volume of 1,230 railcars the rail lines would incur additional daily equipment expenses totaling $28,659.

Potential flood related operation and equipment expenses to the rail lines by flood event are shown below in Table 3-33 - Railroad Damages by Flood Event.

TABLE 3-33 RAILROAD DAMAGES BY FLOOD EVENT

Flood Event	Duration	Railcars Affected	Reroute Expenses	Equipment Expenses	Total
50-year	4	4920	688,800	229,272	918,072
100-year	4.5	5535	774,900	257,931	1,032,831
200-year	5	6150	861,000	286,590	1,147,590
500-year	6	7380	1,033,200	343,908	1,377,108

Railroad damages were modeled in HEC-EAD to estimate expected annual damages. Applying a 25-year non-damaging event to the HEC-EAD model yields expected annual damage for railroads of $32,200.

3.7 Expected Annual Damage Summary

Table 3-34 summarizes the expected annual damages from flooding along the Chehalis and Skookumchuck Rivers developed by the preceding analyses.

TABLE 3-34 EXPECTED ANNUAL DAMAGE SUMMARY

Damage Category	Expected Annual Damage
Structures	4,059,810
Contents	3,066,330
Clean-up	1,197,010
Temporary Relocation Assistance	116,630
Public Assistance	405,130
Agriculture	115,850
Interstate 5 Delays	129,100
Fill Costs Associated with Elevating I-5	0
Railroad Delays	32,200
Total	**$9,122,060**

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4. PLAN FORMULATION

4.1 Problems and Opportunities

Specific problems addressed by the study include:

- Flood inundation damages to structures and contents
- Transportation delays as a result of flooding
- Quantity and quality of aquatic and riparian fish and wildlife habitats

Opportunities to address these problems include:

- Implementation of flood damage reduction measures in study area to protect structures
- Implementation of environmental measures to protect and restore sensitive fish and wildlife habitats in study area

4.2 Planning Objectives and Plan Formulation Overview

4.2.1 Planning Objectives

The objectives of this project are to:

Engineering Objectives:

1. Reduce flood hazards in the project area to the maximum extent practicable.
2. Decrease the transportation closures during flooding on Interstate Highway 5 and other critical transportation corridors to the maximum extent practicable.
3. Avoid increasing flood risks downstream from the project area.
4. Avoid decreasing any existing low flow benefits provided by Skookumchuck Dam.

Economic Objectives:

5. Reduce flood damage costs in the project area to the maximum extent practicable.

6. Reduce transportation delay costs in the study area to the maximum extent practicable.
7. Be cost-effective for both construction and maintenance.

Environmental Objectives:

8. Avoid adverse impacts to the aquatic environment to the extent practicable. Minimize and compensate for unavoidable adverse impacts to the aquatic environment.
9. Incorporate appropriate fish and wildlife habitat creation, enhancement, and restoration measures to the extent practicable.
10. Comply with all Federal, State, and local regulations, including environmental regulations.

4.2.2 Plan Formulation Overview

To accomplish these objectives, a range of alternative plans were identified and evaluated. This formulation and evaluation process was conducted in three phases.

- *Phase 1:* For the study, seven preliminary alternatives were identified from previous studies, the local sponsor, interested agencies, and tribes. The preliminary alternatives were screened by their capacity to address planning objectives. Those alternatives that addressed objectives were carried forward for further modeling and evaluation.

- *Phase 2:* The final set of alternatives was more rigorously evaluated and screened based upon risk-based benefit cost analysis utilizing the HEC-FDA program. The final alternatives were evaluated both independently and in select combinations. This served to identify the first added elements as well as the performance and residual damages of combinations. This analysis identified the NED plan and supported selection of the preliminary recommended plan.

- *Phase 3:* Finally, in the third phase, several different sizes of the NED plan were further evaluated for optimization of project size.

4.3 Description of Preliminary Solutions

Seven preliminary alternatives were identified for inclusion in the initial plan formulation and evaluation phase. These alternatives were based upon previous studies, new local studies, and interagency and tribal coordination. The preliminary alternatives are listed in Table 4.1 and are described in the paragraphs that follow.

TABLE 4-1 PRELIMINARY ALTERNATIVES

Alternative 1	No- Action Alternative
Alternative 2	Skookumchuck Dam Modifications Alternative
Alternative 3	Overbank Excavation and Flowway Bypass Alternative
Alternative 4	Levee System Alternative
Alternative 5	Flow Restrictors Alternative
Alternative 6	Non-Structural Alternative
Alternative 7	Interagency Alternative

4.3.1 Alternative #1 – No Action Alternative

Under the no action alternative, no project features are implemented. Technical studies conducted in the General Reevaluation Study indicate that this alternative would result in continued flooding in the study area. With no action, expected annual damages are estimated at $10,204,780.

4.3.2 Alternative #2 – Skookumchuck Dam Modifications

4.3.2.1 Objective

This alternative is intended to provide reductions in flooding along the Skookumchuck River. This is needed to address flooding problems in the area including in the town of Bucoda and the City of Centralia. This alternative may also provide some reduction in discharge in the Chehalis River downstream of the confluence with the Skookumchuck River.

4.3.2.2 Relation to Previously Authorized Project

Congress authorized a project modifying Skookumchuck Dam in 1986. The project recommended in the 1984 feasibility report envisioned modification of the existing, private, water supply dam on the Skookumchuck River to provide a maximum of 28,500 acre-feet of flood storage, reducing flood damages in the Skookumchuck valley, the town of Bucoda, and the city of Centralia. Most of the alternative configurations of dam modifications evaluated in this study (and described below) are improvements on the originally authorized project.

4.3.2.3 Description

Skookumchuck Dam is located on the Skookumchuck River at approximately RM 22. The dam was constructed in 1970 to supply water for the Centralia steam generating plant. The dam is an earthfill structure approximately 190 feet high with the top of the dam at elevation 497 feet. The dam has a 130-foot wide uncontrolled spillway, on the left abutment, with a crest at elevation 477 feet. Outlet works consist of two 24-inch Howell-Bunger valves with a combined discharge capacity of 220 cubic feet per second (cfs).

This alternative consists of modifications to the existing Skookumchuck dam for the purpose of providing flood control. The current dam has an uncontrolled spillway at elevation 477 feet and a limited capacity to release water from the reservoir when the pool is lower than elevation 477 feet. As a result, the current project configuration provides little flood control benefit since most incoming flow is passed through the reservoir with little attenuation. There is currently about 11,000 acre-feet of storage space available in the reservoir between elevation 455 feet (proposed lower elevation of flood control pool) and 477 feet.

Future modifications to the dam for flood control purposes could include modification of the outlet works to allow a maximum flood storage pool of elevation 492 feet (compared to the current maximum flood pool elevation of 477 feet). Modifications would also likely include additional low-level outlet works to allow the rapid evacuation of stored water above an elevation of about 455 feet. Storage of water to a maximum pool elevation of 492 feet would add an additional 9,000 acre-feet of flood control storage to the reservoir such that the total storage space between elevations 455 and 492 feet would be about 20,000 acre-feet.

4.3.2.4 Dam Safety Considerations

Any proposed modifications to Skookumchuck Dam must enable the project to safely pass the Probable Maximum Flood (PMF) outflow of 32,500 cfs at a maximum design pool elevation of 492 feet. The dam embankment elevation must be sufficient to prevent overtopping during the PMF, while accounting for contingencies such as surcharge, wind wave runup, and embankment settlement. The dam embankment currently has a top elevation of 497 feet. The maximum design pool level is at elevation 492 feet. Five feet between the top of the dam and the maximum pool level is considered adequate freeboard.

USACE conducted additional studies during the General Reevaluation Study to assess the seismic stability of the dam. This was due to uncertainties about the nature of foundation materials and properties, foundation liquefaction, and stability. In the investigations conducted by the Corps in 2001, based on recent seismic information, the study concluded that the sandy gravel soils underlying the silts appear to be liquefiable under all design Maximum Credible Earthquake (MCE) ground motions. In 2001, a similar stability analysis was performed utilizing subsurface explorations, the liquefaction data, and seismic hazard analysis from recent studies. This included evaluation of the existing static and post-seismic stability of the downstream slopes of the dam and berm using a limit-equilibrium approach. The extent of liquefied soils is uncertain beyond the area of investigations with Becker and SPT borings, thus slope failures were calculated for five different ranges of liquefied soils. The calculations indicate a factor-of-safety below 1.0 for conditions where liquefied soils are present from the core to the toe of the downstream berm. This is an issue that will be addressed by FERC and the current owner of the dam prior to the local sponsor taking ownership.

4.3.2.5 Reservoir Regulation Considerations

USACE developed a preliminary flood control operation rule curve as part of its flood control operations investigation (USACE, 1992). The USACE rule curve provided flood control storage of 11,900 acre-feet between elevations 453 and 477 feet, from November 1 to February 1. After February 1, the reservoir would be allowed to refill. Drawdown of the reservoir would begin each year in early to mid September and would continue until elevation 453 feet was reached, usually around the first of November.

The current proposed dam modifications would provide flood control storage of approximately 20,000 acre-feet between pool elevation 455 and 492 feet. A new reservoir operation rule curve similar to the current USACE rule curve will have to be developed for the flood control operation during the optimization phase of this study.

4.3.2.6 Skookumchuck Dam Modifications, Sub-alternatives

Four basic alternatives for modifications at Skookumchuck Dam are being studied, and they are listed below.

- Alternative 2B1 – Spillway Sluices with Gates and Rubber Crest Weir
- Alternative 2B2 – Short Tunnel with Gates and Rubber Crest Weir
- Alternative 2B3 – Tainter Gates in Rock Cut with Rubber Crest Weir
- Alternative 2B4 – Tainter Gates Rock Cut with Emergency Spillway

These alternatives were chosen based on analysis and findings from previous studies. The following sections describe each of the alternatives in greater detail.

4.3.2.7 Alternative 2B1 - Spillway Sluices with Gates and Rubber Crest Weir

In this alternative, a section of the existing ogee spillway would be removed and a new spillway section containing three gated sluices would be constructed. The three sluice gates would each be approximately 10 feet wide and 10 feet high. An emergency bulkhead would be installed to allow for dewatering of the gates.

Design Objectives and Description:

- Pass PMF discharge event of 32,500 cfs
- Provide and maintain dam safety under all conditions
- Provide flood control storage
- Maintain provision of existing water supply demands
- Modify spillway to enable the use of the 15 feet of reservoir storage between elevation 477 and 492 feet for flood control and provide the PMF discharge capability

- Add a 15-foot high by 130-foot wide inflatable rubber weir to the existing spillway crest
- Excavate and lower the spillway ogee crest to make room for the new spillway sluices

4.3.2.8 Alternative 2B2 – Short Tunnel with Gates and Rubber Crest Weir

This alternative would consist of constructing an intake structure just upstream of the right abutment of the existing spillway bridge. The intake would lead to a short tunnel constructed in the rock forming the left abutment of the embankment dam. The intake would have two 8-foot by 11-foot slide gates. The tunnel would vary in shape from a 16-foot diameter horseshoe to a 10-foot diameter conduit. Flow would discharge through the tunnel into the existing spillway chute.

Design Objectives and Description:

- Due to concerns that the left abutment rock may be highly weathered or fractured, and thus not very suitable for tunneling, it was assumed that the tunnel would be constructed as a cut and cover structure.
- Cut down trench in stages with rock anchors being placed prior to the next excavation cut
- Construct a cast-in-place concrete tunnel at the bottom of the trench.
- Excavate approximately 12,600 cubic yards of rock for tunnel construction.
- Construct concrete walls at both the upstream and downstream ends of the trench and backfill the space between
- Drill new grout curtain holes to prevent the flow of water through the dam embankment
- The intake structure would be a freestanding tower with an invert elevation of 438 feet, and a top deck at elevation 497 feet.
- The tower would be approximately 28 by 30 feet in plan, and would contain the two control gates, two guard gates, and all the necessary hydraulic control equipment.
- An inclined trashrack would be provided at the tunnel entrance, as would bulkhead slots.
- The existing uncontrolled overflow spillway would be modified, and a 15-foot high inflatable rubber weir would be constructed on top.
- The outlet tunnel would be designed to discharge up to 8000 cfs during PMF with the remaining 24,500 cfs passing over the overflow spillway.

4.3.2.9 Alternative 2B3 – Tainter Gates in Rock Cut with Rubber Crest Weir

This alternative is similar to Alternative 2B2 described above. This alternative would consist of constructing an intake structure just upstream of the right abutment of the existing spillway bridge. The intake would lead to a channel constructed in the rock forming the left abutment of the dam. The intake would have a single 16-foot wide by 15-foot high tainter gate. Flow would discharge through the channel into the existing spillway chute.

Design Objectives and Description:

- A cast-in-place concrete lining would be constructed.
- Approximately 12,600 cubic yards of rock would have to be excavated for channel construction. A bridge structure would be incorporated to allow vehicles to pass over the outlet channel.
- New grout curtain holes would be drilled to prevent the flow of water through the dam embankment.
- The intake structure would be a freestanding tower with an invert elevation of 438 feet, and a top deck at elevation 497 feet.
- An inclined trashrack would be provided at the tunnel entrance, as would bulkhead slots.
- The existing uncontrolled overflow spillway would be modified, and a 15-foot high inflatable rubber weir would be constructed on top.
- The outlet channel would be designed to discharge up to 8000 cfs during PMF with the remaining 24,500 cfs passing over the overflow spillway.

4.3.2.10 Alternative 2B4 – Tainter Gates in Rock Cut with Emergency Spillway

The alternative includes a rock cut and tainter gates similar to Alternative 2B3; however, the rock cut and gates would be sized to pass the entire PMF flow. The existing overflow spillway would be raised to the reservoir freeboard elevation, and would serve as an emergency spillway. Alternative 2B4 consists of four main features:

- Construction of a new reinforced concrete control structure directly in the existing spillway discharge chute [SDC].
- Reconstruction of the existing SDC.

- Excavation of a new intake channel upstream of the new control structure.
- Excavation and rock bolting of SDC rock walls.

Advantages of Skookumchuck Dam modification Alternative 2B4 include:

- 2B4 is the only alternative that would pass the revised PMF of 32,500 cfs at a pool elevation of 492 while also providing a means of emergency control.
- Although 2B4 would probably require replacement of the existing low flow intake access bridge pier, it provides excellent unrestricted maintenance access to the new control structure and eliminates need for maintenance activities in the vicinity of the existing skewed access bridge and spillway 'bottleneck.'
- Relocating and lowering the crest of the spillway ogee 34 feet essentially eliminates the 'fill and spill' method of operation that has been used since dam construction. 2B4 would allow the dam to store spring inflows for possible summer fish augmentation releases.
- 2B4 provides improved hydraulic discharge conditions by allowing releases directly into the SDC.
- 2B4 provides a new low flow fish passage pipe.

4.3.3 Alternative #3 – Overbank Excavation and Flowway Bypass

4.3.3.1 Objective

The flowway bypass and overbank excavation features were developed in an effort to 1) reduce flooding in the City of Chehalis and to prevent State Route 6 (SR6) from overtopping in large floods through floodplain modification and 2) to reduce flooding of Interstate Highway 5 and the City of Centralia by overbank excavation to increase channel capacity in the vicinity of Centralia. It was anticipated that the combination of these two features would provide significant flood damage reduction in these areas.

4.3.3.2 Relation to Previously Authorized Project

In order to provide flood damage reduction along the Skookumchuck River, these features were proposed for implementation in combination with modifications to Skookumchuck Dam.

4.3.3.3 Description

This floodplain modification alternative would consist of three primary components. The first component, common to all alternative variations of this feature, is modifications to Skookumchuck Dam to provide flood control storage. The second component is floodway modifications in the vicinity of Mellen St. Bridge between River Mile (RM) 65.90 and RM 68.25. One of the alternatives would also include modifications to the existing Mellen St. Bridge abutment. The third component is floodplain modifications in the vicinity of Chehalis/SR-6 to provide flood flow bypass and storage.

4.3.3.4 Chehalis/SR6 Area Floodplain Modifications

Design Objectives and Description:

- Reduce flooding in the City of Chehalis between the 13th St. Interchange and the Main St. (SR-6) Interchange, along I-5
- Eliminate floodwaters from the Newaukum River from spilling through Stan Hedwall Park and into nearby Dillenbaugh Creek and then through the railroad openings to the east side of I-5.

Alternative Features:

- SR6 Bridge Modification
- SR6 Flood Bypass
- Chehalis Flowway Bypass Berm

4.3.3.4.1 SR-6 Bridge Area Modifications

- Floodway excavation on the Chehalis River from shortly downstream of the SR-6 Bridge (RM 74.55) to the mouth of the Newaukum River (Chehalis RM 75.08)
- Excavate approximately 800,000 cubic yards of material from the floodway in this reach of the Chehalis River (would result in approximately 1.5 feet of peak flood stage reduction on the lower 1.5-mile reach of the Newaukum River and Dillenbaugh Creek east of I-5, for a flood event such as the February 1996 event; floodway excavation in this area would need to be substantially extended and increased downstream if further flood stage reduction is required.)
- Reconstruct the right bank approach of the existing SR-6 bridge
- Excavate floodway in the SR-6 Bridge area would also likely require extension of the abandoned Riverside Road Bridge 0.25 mile upstream.
- Due to the large volume of excavation required, and the high cost related to the structural work, and the potential magnitude of environmental impact, this alternative was not considered further.
- The SR-6 flood bypass option discussed below provides a similar or better flood reduction benefit in the Chehalis area for less cost and with less environmental impact.

4.3.3.4.2 SR-6 Flood Bypass Works

- Modify a 1,500-foot section of the SR-6 roadway adjacent to an existing oxbow lake at RM 77 to prevent overtopping of SR-6 during floods up to the 100-year event, and to provide a flood flow bypass to the floodplain east of Scheuber Rd.,
- Excavate approximately 250,000 cy of material and elevate the SR-6 roadway to provide a 5-foot vertical clearance for bypassing overbank flows to the floodplain.
- Excavate approximately 60,000 cy (up to a 4-foot excavation depth) of a 500-foot by 1000-foot overbank area west of the oxbow lake between the Chehalis River and the roadway to provide more frequent overbank flow through this area.

4.3.3.4.3 Chehalis Flowway Bypass Berm

- Construct a north-south oriented 1.5-mile long curving berm on the floodplain north of SR-6. This floodplain fill is intended to form a drainage divide for creating two separate hydraulic regimes between the floodplain bypass/storage area and a 3-mile reach of the main stem Chehalis River downstream of the SR-6 Bridge (RM74.6 to RM 71.6).
- Flood flows bypassing through the modified SR-6 overflow site to the floodplain would not return to the river until the flows reach the north end of the floodplain bypass/storage area. Returning flows would discharge first through the existing Scheuber Drainage Ditch and then over the low-lying overbank area between RM 71.6 and RM 72.4 of the Chehalis River.

4.3.3.4.5 Alternative 3A – Centralia Overbank Excavation

Among the variations modeled, floodway excavation between RM 65.90 and RM 68.05 appears to be the most efficient and cost-effective design.

Design Objectives and Description:

- Excavate approximately 2.4 million cy of material.
- The floodway bench elevation was set to an elevation above the summer normal flow stage so that construction activities would be above the water level.
- At the upper end of the excavation around RM 68.05, the bench elevation would be approximately at elevation 158 feet. At the lower end of the excavation reach (RM 65.90), the bench elevation would be approximately at elevation 148 feet.
- The floodway would have an average excavation width of about 600 feet.
- Side slopes of the excavation were assumed to be two horizontal to one vertical (2:1). Channel velocities in the excavation reach would be reduced from a high of almost 8 fps to less than 4 fps.
- The Mellen St. Bridge section of the Chehalis River is one of the most restrictive for flood flows. In order to alleviate this bottleneck, modifications to the bridge area would be necessary. Currently, it is envisioned that the right bank (east bank) would be excavated. In conjunction with the excavation, the bridge would be extended on piers to remain elevated above the excavated floodway.

4.3.3.5 Alternative 3B – Skookumchuck Bypass

This alternative would involve diverting a portion of the flow in the Skookumchuck River during flood events. This secondary overflow channel would start at approximately RM 1.5 of the Skookumchuck River.

Design Objectives and Description:

- Route channel under I-5 at Blakeslee Junction and connect with some existing small lakes, and then a remnant channel of the Chehalis River.
- The channel would empty back into the Chehalis River at approximately RM 60.5, 6.5 miles downstream of the Skookumchuck's confluence with the Chehalis River.
- It was assumed that the channel would be designed to divert up to 5,000 cfs.

4.3.3.6 Alternative 3C – Centralia Hospital Bypass

The bypass channel would start at about RM 68.0 and would end at the mouth of Scammon Creek at RM 65.9. The alignment would run roughly northwest following localized low ground and would pass immediately south of the hospital.

Design Objectives and Description:

- This channel alignment would require the construction of three bridges and would require excavating out lower Scammon Creek.
- The entrance to the bypass channel would be set at approximately elevation 165. This is approximately the water surface elevation for the annual flood event.
- The channel would likely be grass lined and have a rock-armored entrance to prevent scour.

4.3.3.7 Hump Excavation

The “hump” area is located in the Chehalis River at approximately RM 67.1 to RM 65.9. The channel bottom at this location is approximately at elevation 148 feet. This is approximately 10 feet higher than much of the riverbed further upstream. This high bottom elevation appears to restrict flow during the 100-year flood. There have been numerous suggestions that excavation of this ‘hump’ would significantly increase hydraulic capacity of the channel during flood flows, and thus reduce upstream flooding.

To evaluate the effects of the “hump” on hydraulic capacity during flood flows, two excavation alternatives were analyzed. The maximum velocity reductions resulting from either alternative are insignificant in the excavation reach because during a flood, a significant portion of the flow is in the overbank area. Thus, the slight increase in channel area has only a marginal impact on the total flow area. This feature was not examined further.

4.3.4 Alternative #4 – Levee System

4.3.4.1 Objective

This project was designed to reduce flood damages associated with the Chehalis and Skookumchuck Rivers. It also addresses flooding along Salzer Creek, Dillenbaugh Creek, and the Newaukum River. This alternative reduces damages to structures and allows for I-5 to stay open for transportation.

4.3.4.2 Relation to Authorized Project

Various levee alignments in the study area were studied previously by the Corps in the 1970’s. The levee alternative can be combined with Skookumchuck Dam modifications (Alternative 2) to provide more comprehensive flood damage reduction throughout the study area.

The basic Levee Alignment was originally developed through a pervious study (circa 1970's). Local sponsors helped the study team develop a Levee Alternative. The plan was presented at public meetings for their review and comment. Draft reports were completed in 1976 and 1978. The Levee Alternative was dropped when a plan to modify Skookumchuck Dam to add flood control.

4.3.4.3 Description

This alternative consists of constructing a system of levees to protect flood-prone areas in the vicinity of Chehalis and Centralia. Levees would be constructed at selected locations along the Chehalis and Skookumchuck Rivers as well as along several tributaries (i.e., Salzer Creek, Coffee Creek). This alternative was considered both with and without the benefit of flood control operations at Skookumchuck dam. A total of 20,000 acre-feet of flood control storage was assumed available in the Skookumchuck reservoir for the levee plus dam modification alternative.

4.3.4.4 Design Objectives

In reviewing the work of previous studies, considering the increased importance placed on environmental concerns, and conducting site visits with shareholders, it became apparent that much coordination was necessary. This made it important to incorporate as many concerns as possible early in the design effort to avoid impacts later in the study. To facilitate the expedited study some guiding design objectives were considered throughout the project. These objectives also correlate to the project criteria. The following are the guiding design objectives:

- Avoid environmental impacts to the maximum extent possible
- Minimize the environmental impact as much as possible
- Minimize the initial construction and long term maintenance
- Provide a minimum of a 50-year project life
- Minimize project-induced damages, both within the project area and downstream
- Avoid inundating or excavating of hazardous materials
- Maximize the transportation corridor benefits
- Maximize local infrastructure benefits
- Incorporate restoration opportunities into project

In addition, a general assumption in the levee system design was that it would provide 100-year protection from flooding of the Chehalis River. This includes protection from Chehalis River backwater on the tributaries, including on Dillenbaugh Creek, Salzer Creek, China Creek, Coal Creek and the Skookumchuck River.

4.3.4.5 Design Process

The study team took the levee alignment developed in 1970, made refinements based on flood observations in 1990 and 1996. The team investigated the project area, identified areas needing flood protection, aligned the levee to tie into existing levees, and adjusted the alignment to protect existing infrastructure while providing a floodplain. The team also adjusted the original alignment to have the least impact to community (residential) infrastructure, to the environment, and to WSDOT roadways.

Following initial hydraulic modeling, the team re-evaluated the levee segments. Some segments were deleted because 1) protection was not required, and 2) improved alignments were identified. Additional modifications and refinements to the levee plan were based upon coordination with WSDOT and their widening project of I-5, incorporating 1-5 into the levee alignment where practical to reduce costs and minimize environmental impacts.

The standard Corps levee design consists of a 12-foot top width and 2:1 side slopes (2 horizontal to 1 vertical). The fill material must meet the gradation specification and be compacted to Corps standards for levees (shown in Levee Plan Design Appendix). A 6-inch layer of gravel will be placed on the top surface to provide access during flood events and maintenance. Both sides of the levee will be hydro seeded with grass with 4 inches of topsoil over compacted embankment material. Most levees are set back levees, which will not require rock bank protection. For those few areas that do require bank protection. The protection will include 30 inch minus riprap about 3 feet thick, with a 1-foot layer of quarry spalls between the riprap and compacted embankment material.

Environmental Impacts were identified and then avoided to the maximum extent possible. Unavoidable impacts were minimized, with design modifications. For example changing from a levee to a floodwall in certain areas of concern to minimize the footprint of the structure.

Additional factors in the design process included:

- Used 1976 Levee Alignment from previous study that had gone through public review process as a starting point. (Note: the drawings from draft report in 1976/1979 were found, but not text associated with drawing)

- Standard Corps Levee 12' wide and 2:1 horizontal: vertical slopes were assumed as the primary levee design. Variations including vertical wall is tight area may be required in setback areas only.
- Consulted with study manager that has spent 27 years with the Corps working on problems in this basin. (Forest Brooks)
- Toured the basin with "plan-in-hand," with study manager who had been on-site during the 1996 flood event. This event was approximately the 100-year event. High water marks from that event were noted and incorporated into design with minor revisions.
- The plan was drawn onto CADD drawing and distributed to the study team for comments.
- Plan was revised by internal study team, the drawings were sent out externally to local sponsors (county and cities), and agencies
    - Site visit/tour with local sponsors.
    - Site visit/tour with state agencies (Environmental).
    - Meetings with State Department of Transportation
    - WSDOT Requested Levee elevation for I-5 corridor be set at 2.5 ft. above 100-year flood elevation. They are also doing environmental assessment of raising or protecting road.
    - Addressed concerns of culverts/underpasses.
    - Meetings and tours of area with Chehalis Tribe.
    - Meetings with Washington State Department of Ecology to obtain list of known HAZMAT sites and share proposed Levee Alignment.
    - Utilized wetland inventory to minimize and avoid wetland area impacts.
- The design team coordination with agencies included conducting multiple meetings showing plan and requesting comments, submittal of written requests for comments, and provision of study area tours upon request.

4.3.4.6 Levee Alignment

The levee alignment would protect residential and commercial structures, highway and other transportation infrastructure from flooding. Proposed protection would extend along the Chehalis River from approximately River Mile 75 to River Mile 64, along the Skookumchuck River from approximately River Mile 5 to near the mouth, as well as along most of the lower two miles of both Dillenbaugh Creek and Salzer Creek. The proposed levee alignment is displayed in Plate 7.

4.3.5 Alternative #5 – Upstream Flow Restriction Structures, and Upstream Storage

4.3.5.1 Flow Restrictors

Objective:
Flow restrictors are intended to increase water surface elevation upstream of the flow restrictor at low flows providing potential benefits to wetlands and fisheries. Currently there is a lack of off-channel habitat for salmon along the mainstem of the Chehalis River. If spring and summer flows could be backed up into adjoining low areas or disconnected oxbows, without also resulting in a stage increase during the 100-year flood event, then additional off-channel habitat could be created. The increased upstream inundation could also have a potential benefit in regards to increasing groundwater recharge.

Description:

Flow restrictors are any kind of structure that intentionally restricts and holds back flow in order to help reduce downstream flooding, or to increase upstream inundation. Increased upstream inundation can be beneficial for wetlands and fisheries in some cases. It was envisioned that these structures would be much simpler and of smaller scale than flood control dams, as well as less costly and more environmentally friendly.

For all structures, it was assumed that upstream inundation levels would not be allowed to exceed the current hundred-year flood level. Known high water marks from the February 1996 flood were used as the criteria during modeling. For the first site studied, three different structure types were analyzed: a slot structure, a fixed weir structure, and a control type structure. The control type was found to be most effective of the three. For the remaining sites, only a control type structure was considered. Sites included:

- Mainstem Chehalis River at RM 87.56
- Mainstem Chehalis River at RM 89.61
- Mainstem Chehalis River at RM 104.09
- South Fork Chehalis River at RM 0.3
- Lincoln Creek
- Stearns Creek
- Salzer Creek

4.3.5.2 Upstream Storage

The flow restrictor structures discussed earlier show no significant water surface reduction for the hundred-year flood in the Centralia-Chehalis area due to the rather limited volume of flood control storage they would provide. In order to create the volume of flood control storage necessary to effect significant water surface level reductions downstream, three basic alternatives were examined: individual flood control dams, multiple smaller headwater dams, and flood storage dikes on the floodplain. It is anticipated that all three options would have significantly greater environmental impact than the initially proposed flow restrictor structures.

4.3.5.6.1 Upstream Flood Control Dams

USACE investigated five potential locations for large multi-purpose storage dams in the Upper Chehalis River Basin in the course of its flood control studies (USACE, 1982). The five locations consisted of two sites on the Newaukum River, one site on the South Fork Chehalis River and two sites on the mainstem of the Chehalis River, upstream of the Newaukum River. All five alternatives were determined to be economically infeasible.

4.3.5.6.2 Small Headwater Dams and Flood Storage Dikes on the Floodplain

In its studies, USACE also investigated the feasibility of building several small headwater dams (USACE, 1982). USACE evaluated twelve sites in the drainage above Centralia-Chehalis. The combined flood storage capacity of all twelve dams would be only 14,500 acre-feet, with an estimated reduction in flow at Grand Mound of 3,000 cfs for a 100-year flood event. The 3,000 cfs flow reduction would result in flood stage reduction of approximately 3 inches. In 2001 dollars, the USACE estimated cost to construct the twelve dams would be approximately $118 million, which would equate to approximately $472 million dollars per foot of flood stage reduction. Because of the poor benefit-to-cost ratio, this alternative was not investigated further. The Corps also investigated the feasibility of flood storage areas in the floodplain. This would be accomplished by enclosing a large area with a dike. During floods, the floodwaters would overflow into the dike enclosed storage area. Stored floodwaters would then be released slowly through a downstream outlet. This type of flood storage operation would not be as efficient and effective as that provided by a flood control dam. Placing flood control storage in the floodplain is also not as effective as utilizing storage in the headwaters. In the floodplain, the flows are already rather attenuated and a much larger storage volume is required for an equivalent stage reduction.

4.3.6 Alternative #6 – Non-Structural Alternative

4.3.6.1 Objective

The intent of the non-structural alternative was to formulate a viable non-structural solution to reduce flood damages throughout the study area.

4.3.6.2 Relation to Authorized Project

Does not include incorporation of authorized project at Skookumchuck Dam.

4.3.6.3 Description

Non-structural measures include watershed management, flood-proofing structures, evacuation plans, and removal of structures from the floodplain. Watershed management includes such actions as reforestation, timber harvest control, and restrictions on floodplain development. These measures do not directly address flood elevations, but reduce economic damages and safety hazards. Flood-proofing structures would require elevation of residential buildings to the 100-yr flood level, and making commercial first floor buildings watertight. Also, no new construction would be allowed in the floodplain. Evacuation plans assist floodplain dwellers in avoiding flooding impacts. Relocation of a selected number of structures in the floodplain, or even all the structures in the floodplain, has been proposed. Because there are no flood control structures proposed for construction, no footprint value is calculated. However, overall impact area would extend throughout the upper Chehalis basin. For this reason, the entire project area, plus 10%, is included as the overall impact area (41,360 acres).

Impacts are negligible for this proposed alternative. No structures are proposed for construction and several of the components of this alternative may actually improve floodplain and river conditions. Removal of structures and control of development would reduce the impervious surface area in the floodplain, improving groundwater recharge and baseflows. Reforestation would increase the amount of riparian vegetation and increase LWD recruitment.

Any combination of restoration measures could be selected to provide restoration above the requirements for mitigation, since mitigation is not required for this alternative.

4.3.7 Alternative #7 – Interagency Committee Alternative

4.3.7.1 Objective

In the fall of 1996 Washington State Department of Ecology (WDOE) set up the Chehalis Basin Local Action Team, an internal team, to work with local governments and build partnerships to solve water problems in the basin. In 1998, a Technical Committee was formed, comprised of representatives of local, state and Federal agencies and tribes. During 1998, the Technical Committee formed an Alternatives Subcommittee to identify and evaluate potential flood hazard reduction measures and to develop alternatives for meeting specific flood hazard reduction goals.

The purpose of this alternative is to provide short and long-term actions that will reduce flooding hazards to the Centralia and Chehalis area residents, while at the same time, restore and enhance river hydrology and floodplain functions to support the basin's salmonid habitat base.
This alternative seeks to reduce flood hazards and increase floodwater storage by focusing first on regulatory and voluntary measures. The connectivity of the Chehalis River to its floodplain is maintained and enhanced using land use and development regulations before implementation of any costly structural solutions. In addition, this alternative seeks to maintain vital Interstate 5 and State Route access by constructing a traffic by-pass and by reducing flood frequency and duration. Also advocated are the uses of flood plain easements, acquisition of frequently flooded areas and structures, relocation or elevation of structures, and improved upland water storage. Finally, the alternative is presented as a sequence of actions that require analysis before additional actions are proposed.

4.3.7.2 Relation to Authorized Project

This alternative was evaluated in combination with the modifications to Skookumchuck Dam.

4.3.7.3 Design Process Description

The Alternatives Subcommittee reviewed a variety of different flood hazard reduction measures and used a format of facilitated workshops to sift through potential combinations of measures. The approach that was agreed to begins by describing the major elements (these could be individual measures or measures in combination) that make up the combination alternative. These measures include:

- *Measure 1 – Moratorium on Floodplain Development.* In the interim, a moratorium on floodplain development is recommended until the new flood insurance rate maps are adopted. Lewis County, and possibly Grays Harbor and Thurston counties, and area cities should enact interim regulations that restrict new fills until the new FEMA floodplain and floodway maps are prepared and adopted.

- *Measure 2 - Adopt New FEMA Floodplain and Floodway Maps.* Define a new floodway based on a 0.2-foot rise in the water surface profile. Use the new topographic information for this analysis. These data are required for the accurate evaluation and implementation of this alternative. The 0.2 rise and the new 100-year floodplain will be used to develop or update floodplain management plan and regulations governing future floodplain development.

- *Measure 3 – Develop Flood Warning System.* Develop and implement a basin-wide flood warning system. Ensure that the system is well coordinated and interconnected among the various jurisdictions and agencies that provide emergency services.

- *Measure 4 - Restrict Floodway Development.* Restrict development (residential, commercial, industrial) in the newly defined floodway; and have outstanding approved filling/floodplain development activities provide a hydraulic analysis to show a 0.2 ft rise or less in the floodwater surface elevation. Jurisdictions would review pending permits to ensure that the proposed development does not increase flood damage risk to adjacent, upstream, and downstream properties. Jurisdictions should also consider establishing a time limit on development permits.

- *Measure 5 – Restrict Development in Flow Path.* In addition to defining the 0.2 foot floodway as described in item #1 above, development should also be restricted within additional critical portions of the floodplain, specifically in areas considered to be significant flow paths. Flow paths are naturally occurring swales, which are normally dry, but which have historically conveyed significant amounts of flowing water during flood stage. These flow paths could be established by identifying split flow conditions as part of the HEC-RAS analysis, or by simply identifying flow paths from photos and observations. Generally these flow paths have floodwaters greater than 3 feet deep, and velocities greater than 3 feet per second, during the 100 year event. If blockage of a flow path produces more than 0.2 foot backwater, then it is a flow path and will be protected from future development and/or fill under this alternative.

- *Measure 6 – Restrict Floodplain Filling.* Restrict new filling by requiring that fill be mitigated by removal of equal volume of fill elsewhere in the floodplain or floodway. Cut and fill balances should be retained within the project site whenever possible.

- *Measure 7 – Preserve/Enhance Floodplain Flood Storage.* Conduct an analysis to quantify the potential amount of floodplain storage provided by existing, expanded and enhanced floodwater storage areas. Potential areas are south of SR6 in the Newaukum basin, South

Fork of the Chehalis River, and the area bordered by Ceres Hill and White Road, proposed WSDOT wetlands mitigation site near Stan Hedwall Park, existing wetlands, connections to oxbows and historic flow paths, SR6 floodplain storage, and upland storage. The analysis will provide an assessment of the storage capacity that could be gained by removing barriers that are no longer used or can be redesigned, such as railroad grades, roadways and bridges. The analysis will generate hydrographs demonstrating the role of storage, and may be used to implement measures such as voluntary buy-outs, purchase of flow easements, etc.

- *Measure 8 – Restrict Upland Land Uses.* Utilize other land use measures that lower and slow the hydrologic response of the basin. For example, consider upland vegetation coverage, reduced development densities, and reductions in the amount of impervious surfaces. Avoid impacts to wetlands, preserve and maintain wetlands, critical areas, and farmlands that supply floodplain storage capacity.

- *Measure 9 – Flood Audits.* Conduct a flood audit for the cities of Chehalis, Centralia, and surrounding communities in order to determine which structures would benefit from raising, flood proofing, or acquisition.

- *Measure 10 – Upgrade Stormwater Management Systems.* Perform analyses to determine the detention effects of a 25-year design storm versus a 100-year design storm throughout the basin. Stormwater management is an integral element of the National Flood Insurance Program (NFIP). It regulates new development throughout the watershed to ensure that post-development runoff is no worse than pre-development runoff; and it regulates new construction to minimize soil erosion, and protect water quality. Stormwater management is also mitigation for development. This alternative is based on judicious planned development to reduce flood reduction risks. However, mitigation for development is inadequate when communities do not have a local stormwater management program or use less than the 100-year design storm for their local programs. With this in mind, it is imperative that stormwater management programs are implemented consistently throughout the basin to mitigate for development. It is also equally vital that the design criteria used for these programs are high enough to be effective. Detention for design storms shall be based on the 100-year event. Use of a 100-year, 24-hour design storm is a standard national and State design criteria for stormwater management. This design storm should not be confused with a 100-year flood event, which is based on physical characteristics, geology, climatologic, antecedent conditions, land use, river morphology, size, and development density of the watershed.

- *Measure 11 – Improve Alternative Transportation and Emergency Access Routes.* Identify alternative transportation and emergency access routes. The proposed priority would be to lower flood levels so that Interstate 5 and the State Routes are not closed during a 50-year storm event and to maintain emergency access routes on local roads up to a 25-year event. The local medical facility is on Cooks Hill in Centralia, and the two routes via Scheuber Road and Mellen Street are linked to SR6 and I-5. Improvements will be needed on portions of Scheuber Road along with modifications on the SR6 bridge, Mellen St Bridge, and I-5. This local access road could be used as an I-5 alternate route. Depending on the severity of the flood, the local route may be closed during severe flooding conditions. Depending on the need to keep local roads open, there may be additional modifications to SR6.

- *Measure 12 – Expand Capacity of Centralia-Chehalis Airport Dike Culverts.* This measure proposes modifications to culverts and levees affecting the duration of flooding on northbound lanes of I-5 (modifications would reduce duration only -- not the incidence or frequency of flooding). Recommended measures are to install flap gates and expand culverts to direct water to drain northerly. Flap gated culverts will be needed on the west side of the highway to drain the airport and the southbound lanes of Interstate 5. An additional flap gate will be needed on the east side in order to drain the northbound lanes of Interstate 5. Presently it is necessary to excavate an opening in the levee to release the trapped water on the west side, and the east side must flow through a small diameter culvert, which takes about 40 additional hours to drain down. This alternative would reduce the highway closure time from 72 hours to about 30 hours. This would cut economic losses associated with the closure of I-5 by more than half.

- *Measure 13 – Off Channel Storage and Upstream Flow Restriction Structures.* Investigate the flood reduction achieved by installing flow restrictors (such as artificial log jams or agricultural storm water ponds) at strategic locations that would allow for significant amounts of water to be temporarily stored during normal and large flood events. In all areas above flow restrictors and where buyouts or flood easements take place, the following restoration activities are recommended: 1) Restore floodplain and riparian areas via revegetation and livestock exclusion, 2) Maximize stormwater mitigation opportunities from urban areas, 3) Mitigate agricultural ditch runoff (agricultural stormwater ponds), 4) Restore wetland complexes (enhancement of summertime flows), 5) Re-establish oxbow/side channel habitat functions as they relate to over winter/summer habitat for salmon.

- *Measure 14 – Chehalis Flowway Bypass.* Begin by adding the floodwater bypass measure at SR6 (measure is defined in Technical Memorandum No. 3) in combination with voluntary buy-outs and flood easements required to attain enhanced floodwater storage capacities in areas identified in measure 7. Then, re-assess and if still needed to reach goals go to measure 15.

- *Measure 15 – Excavate Overbank Downstream of "Hump".* Add a carefully designed overbank excavation downstream of the "hump". Any excavation should be strategically designed to align with old side channels, and to remove invasive species such as reed canary grass and restore native vegetation. Excavation should not be located where the banks are functioning well and mature riparian forest is established.

- *Measure 16 – Elevate Segments of Interstate Highway 5*. Add elevation to specific segments of I-5.

- *Measure 17 – Modify Skookumchuck Dam.* Finally, add modifications of Skookumchuck Dam to improve flow control, but do not increase the storage.

- *Other Measures If Required.* Following a detailed analysis of the flood hazard reduction achieved by the above listed measures, this alternative will consider a sequence of structural measures.

4.4 Hydrologic and Hydraulic Assessment of Preliminary Alternatives

The following paragraphs provide a brief summary of the hydrologic and hydraulic performance aspects of preliminary alternatives 2, 3, 4, 5, and 7. Alternatives 1(No Action), and 6 (Non-Structural) did not involve hydraulic modifications to evaluate in the assessment.

4.4.1 Alternative 2 – Skookumchuck Dam Modifications

Summary of Hydraulic Aspects of Alternative 2:

1. Modifications to the Skookumchuck dam as currently proposed for the purposes of flood control operation would have a significant impact on the areal extent of flooding along the Skookumchuck River and a significant reduction in the peak stage of the Skookumchuck River. Reductions in peak stage would generally be greatest within the reach closest to the dam and would generally lessen in a downstream direction.
2. Flood control operations using the current maximum pool of elevation 477 feet (11,000 acre-feet of storage above elevation 455 feet) would be sufficient to provide significant flood reduction benefits along the Skookumchuck River below the dam during most moderate flood events (i.e., 2-year to 25-year flood events).
3. Flood control operations using an increased maximum pool of elevation 492 feet (20,000 acre-feet of storage above elevation 455 feet) would be sufficient to provide significant flood reduction benefits along the Skookumchuck River below the dam during most moderate to large flood events (considerable flood damage reduction would likely be realized during a 50-year event and possibly during a 100-year event).
4. Flood damage reduction benefits from this alternative are expected to be limited along the Chehalis River. No flood reduction benefits would be provided to the City of Chehalis. Very small reductions in the peak stage (up to 0.2 feet during a 100-year event) may occur in the Chehalis River between RM 70 and RM 67 (Chehalis/Skookumchuck confluence). Slightly larger reductions in peak stage (possibly up to 0.5 feet during a 100-year event) could occur in the Chehalis River downstream of RM 67. Flood reduction benefits to the Chehalis River from this alternative are limited given the large size of the Chehalis River basin (895 square miles at Grand Mound) relative to the small basin area draining to the Skookumchuck reservoir (on the order of 60 square miles).

4.4.2 Alternative 3 – Excavation and Flowway Bypass

Summary of Hydraulic Aspects of Alternative 3:

1. The bypass-only alternative would cause a relatively significant reduction in the areal extent of flooding and a significant reduction in the peak stage of the Chehalis River in the vicinity of the two bypass channels. Peak stage would be reduced by up to 3 feet in the vicinity of the bypass channels (RM 77 to 74 and RM 73 to 66) during the 10-year event and by up to 4 feet during the 100-year event.
2. The bypass-only alternative would cause a slight increase in the peak stage of the Chehalis River downstream of RM 66. Peak stage downstream of RM 66 would increase by about 0.2 to 0.7 feet during a 10-year event and increase by about 0.1 to 0.4 feet during a 100-year peak. Downstream increases in peak stage are attributed to a more efficient routing of flood flows through the Chehalis-Centralia reach due to the bypass features.
3. With the exception of a very short reach of the Skookumchuck River near the Chehalis River confluence (RM 0 to 1), the bypass-only alternative would have no impact on stage and attendant flooding in the Skookumchuck River.
4. The bypass plus Skookumchuck dam modification alternative would cause a relatively significant reduction in the areal extent of flooding and a significant reduction in the peak stage of the Chehalis River in the vicinity of the two bypass channels (primarily attributed to the bypass features). Peak stage would be reduced by up to 3 feet in the vicinity of the bypass channels (RM 77 to 74 and RM 73 to 66) during the 10-year event and by up to 4 feet during the 100-year event.
5. The bypass plus dam modification alternative would have little to no impact to the peak stage of the Chehalis River downstream of RM 66. Peak stage downstream of RM 66 would be essentially equal to peak stage in this reach under existing conditions. Flood control operations at the modified Skookumchuck dam would essentially offset any stage increases in this reach attributed to the bypass channels.
6. The bypass plus dam modification alternative would cause a relatively significant reduction in the areal extent of flooding and a significant reduction in the peak stage of the Skookumchuck River downstream of the dam. Reductions in peak stage would generally be greatest within the reach closest to the dam (peak stage reductions of 2 to 6 feet during the 100-year event) and would generally lessen in a downstream direction

(peak stage reductions of 1 to 3 feet in the vicinity of Centralia during the 100-year event). With the exception of a very short reach of the Skookumchuck River near the Chehalis River confluence (RM 0 to 1), flood reductions along the Skookumchuck River under this option are attributed solely to modified flood control operations at the dam.

4.4.3 Alternative 4 – Levee System

Summary of Hydraulic Aspects of Alternative 4:

1. The levee-only alternative would cause a relatively significant reduction in the areal extent of flooding in the Chehalis River valley in the Chehalis-Centralia reach. Although the levees would cause relatively small (less than 1 foot up to a 100-year event) increases in peak stage within the Chehalis River channel, water levels would be reduced in targeted areas of the floodplain where damages are most likely to occur. Slight increases in the peak stage within the Chehalis River channel would occur as a result of the levees keeping a higher proportion of the flow confined to the channel (resulting in less flow leaving the channel and entering overbank and floodplain areas).
2. The levee-only alternative would cause a slight increase in the peak stage of the Chehalis River downstream of RM 66. Peak stage downstream of RM 66 could increase by about 0.1 during a 10-year event and could increase by up to 0.15 feet during a 100-year peak. Slight downstream increases in peak stage are attributed to a more efficient routing of flood flows through the Chehalis-Centralia reach due to the levee system.
3. The levee-only alternative would cause a relatively significant reduction in the areal extent of flooding in the lower Skookumchuck River valley in the Centralia area. This is based on the assumption that a system of continuous levees would be placed along both banks of the Skookumchuck River along the lower four miles of the river. Although the levees would cause moderate (up to 1 foot during a 10-year event, up to 3 feet during a 100-year event) increases in peak stage within the Skookumchuck River channel, water levels would be reduced in targeted areas of the floodplain where damages are most likely to occur. Increases in the peak stage within the Skookumchuck River channel would occur as a result of the levees keeping a higher proportion of the flow confined to the channel (resulting in less flow leaving the channel and entering overbank and floodplain areas).

4. The levee plus Skookumchuck dam modification alternative would have a similar reduction in the areal extent and depth of flooding along the Chehalis River as the levee only option. Additional flood damage reduction benefits to the Chehalis River from the modification of Skookumchuck dam would be limited and would be primarily limited to reaches downstream of the Chehalis/Skookumchuck confluence. Possibly the biggest benefit of adding flood control regulation at Skookumchuck dam to this alternative is that the slight increase in stage in the Chehalis River downstream of Centralia attributed to the levee system would be mitigated. As a result, the peak Chehalis River stages downstream of Centralia under the levee plus dam modification option would likely be lower relative to the peak stages under existing conditions.
5. The levee plus Skookumchuck dam modification alternative would cause a significant reduction in the areal extent and depth of flooding along the Skookumchuck River. The assumed system of levees along the lower four miles of the river would protect most of Centralia from Skookumchuck River related flooding, and flood control operations at the dam would cause a significant reduction in stage within the channel.

4.4.4 Alternative 5 – Upstream Flow Restriction Structures

Summary of Hydraulic Aspects of Alternative 5

1. Both options of the flow restrictors would lower stage along the mainstem Chehalis River within the study area (i.e., Chehalis-Centralia area) but would have essentially no impact to stage in the Skookumchuck River (i.e., the flow restrictors have no beneficial impact on flooding attributable to the Skookumchuck River).
2. Option 1 (a single flow restrictor) would lower peak stage in the Centralia/Chehalis area (damage area) on the order of 0.1 to 0.3 feet during a 10-year flood event. Option 1 would lower peak stage in the damage area on the order of 0.1 to 0.3 feet during a 100-year flood event.
3. Option 2 (four separate flow restrictors) would lower peak stage in the damage area on the order of 0.1 to 0.45 feet during a 10-year flood event. Option 2 would lower peak stage in the damage area on the order of 0.1 to 0.5 feet during a 100-year flood event.
4. Both options would have little impact on the areal extent of flooding in the damage area.
5. Based on the assumption of a 20-foot high structure, each flow restrictor could cause a relatively significant increase in the areal extent and depth of flooding upstream of the

structure. For instance, a single flow restrictor located at RM 87.54 on the Chehalis River would apparently worsen flooding across sections of State Route 6 and would likely worsen flooding at homes and property upstream of the structure. The increased stage associated with a single flow restrictor at RM 87.54 could reach as far as 4 miles upstream of the structure (personal communication with Albert Liou of PIE, Inc. 11/6/01). There may also be short-term impacts to fish passage and sediment transport associated with the flow restrictors.

4.4.5 Alternative 7 – Interagency Committee Alternative

This alternative seeks to reduce the impacts of flooding by focusing first on regulatory and voluntary measures. This alternative is presented as a sequence of measures that require analysis before additional measures are proposed. The sequence of measures is listed below:

1. Moratorium on floodplain development.
2. Adopt new FEMA flood maps.
3. Improve flood-warning system.
4. Restrict floodway development.
5. Restrict development in flow paths.
6. Restrict floodplain filling.
7. Preserve/enhance floodplain storage.
8. Restrict upland land uses.
9. Flood audits.
10. Upgrade stormwater management systems.
11. Improve alternative transportation and emergency access routes.
12. Expand capacity of Centralia-Chehalis airport dike culverts.
13. Use of upstream flow restrictor structures.
14. Construction of Chehalis (SR 6) flowway bypass channel.
15. Excavation of the “hump” in the Chehalis River channel near Galvin.
16. Elevate segments of Interstate Highway 5.
17. Modify Skookumchuck dam to provide flood control.

Items 1 through 11 are primarily non-structural items and as such the effects of these items cannot be modeled using the UNET hydraulic model. Items 12 through 17 are mostly structural in nature and therefore can be simulated using the UNET model. Three options were evaluated for the current analysis. Option 1 simulates the effects of Items 12 through 15; Item 13 is assumed to consist of four flow restrictors as discussed under Alternative 5, Item 14 is considered as discussed under Alternative 3. Option 2 simulates the effects of Items 12 through 16 (Items 13 and 14 are simulated as described under Option 1). Option 3 simulates the effects of Items 12 through 17 (Items 13 and 14 are simulated as described under Option 1, Item 17 (Skookumchuck dam modification) assumes a maximum of 11,000 acre-feet of flood control storage (maximum pool elevation of 477 feet).

Summary Of Hydraulic Aspects Of Alternative 7:

(1) Option 1 would reduce peak flood stages in the Chehalis River significantly in the vicinity of the SR 6 bypass (up to a maximum peak stage reduction of approximately 3.5 feet for the 10-year and 100-year flood events) but would result in little to no stage reductions downstream of the bypass (i.e., peak stage reductions in the Chehalis River downstream of RM 72 would be on the order of 0 to 0.5 feet during the 100-year event, no apparent reductions in peak stage would occur in the Chehalis River downstream of RM 72 during small to moderate [i.e., up to a 25-year event] flood events).
(2) Option 1 would have no impact (i.e., no stage reduction) in the Skookumchuck River.
(3) Option 2 would reduce peak flood stages in the Chehalis River significantly in the vicinity of the SR 6 bypass (up to a maximum peak stage reduction of approximately 3.5 feet for the 10-year and 100-year flood events) but would result in little to no stage reductions downstream of the bypass (i.e., peak stage reductions in the Chehalis River downstream of RM 72 would be on the order of 0 to 0.5 feet during the 100-year event, no apparent reductions in peak stage would occur in the Chehalis River downstream of RM 72 during small to moderate [i.e., up to a 25-year event] flood events).
(4) Option 2 would have no impact (i.e., no stage reduction) in the Skookumchuck River.
(5) Option 3 would reduce peak flood stages in the Chehalis River significantly in the vicinity of the SR 6 bypass (up to a maximum peak stage reduction of approximately 3.5 feet for the 10-year and 100-year flood events). Option 3 would reduce peak flood stages in the Chehalis River downstream of the bypass as a result of flood control operations at Skookumchuck dam. Reductions in the peak stage in the Chehalis River downstream of RM 72 would be modest (on the order of 0.1 to 0.5 feet during a 10-year event, slightly greater during a 100-year event).

(6) Option 3 would significantly reduce the peak stage in the Skookumchuck River as a result of flood control operations at Skookumchuck dam. Reductions in peak stage would generally be greatest within the reach closest to the dam (peak stage reductions of 1.5 to 3.5 feet during the 100-year event) and would generally lessen in a downstream direction (peak stage reductions of 1 to 2 feet in the vicinity of Centralia during the 100-year event).

(7) All three options were simulated based on the assumption of the installation of four upstream flow restrictors (see Alternative 5). Based on the assumption of a 20-foot high structure, each flow restrictor could cause a relatively significant increase in the areal extent and depth of flooding upstream of the structure. For instance, a single flow restrictor located at RM 87.54 on the Chehalis River would apparently worsen flooding across sections of State Route 6 and would likely worsen flooding at homes and property upstream of the structure. The increased stage associated with a single flow restrictor at RM 87.54 could reach as far as 4 miles upstream of the structure (personal communication with Albert Liou of PIE, 11/6/01). There may also be short-term impacts to fish passage and sediment transport associated with the flow restrictors.

4.5 Phase 1 - Screening of Preliminary Alternatives

4.5.1 Phase 1: Preliminary Alternatives Screening Criteria

Section 4.2.1 listed the planning objectives for this project. In plan formulation, alternatives were screened by their capacity to meet objectives. In the initial screening phase, the plan formulation team reviewed results of preliminary modeling of initial alternatives to assess their ability to address the following criteria.

Engineering Criteria:

1. Reduce flood hazards in the project area to the maximum extent practicable.
2. Decrease the transportation closures during flooding on Interstate Highway 5 and other critical transportation corridors to the maximum extent practicable.
3. Avoid increasing flood risks downstream from the project area.
4. Avoid decreasing any existing low flow benefits provided by Skookumchuck Dam.

Economic Criteria:

5. Reduce flood damage costs in the project area to the maximum extent practicable.
6. Reduce transportation delay costs in the study area to the maximum extent practicable.
7. Be cost-effective for both construction and maintenance.

Environmental Criteria:

8. Avoid adverse impacts to the aquatic environment to the extent practicable. Minimize and compensate for unavoidable adverse impacts to the aquatic environment.
9. Incorporate appropriate fish and wildlife habitat measures to the extent practicable.
10. Comply with all Federal, State, and local regulations, including environmental regulations

The first phase in the plan formulation process was to utilize the project criteria to screen each alternative. The formulation team used most current design, cost and modeling information that had been developed to determine if an alternative could possibly meet the criteria. If it was determined that an alternative could potentially meet all project criteria, or that it could be combined with other alternatives to help them meet all project criteria, then that alternative was carried forward for further evaluation in Phase 2. Several of the alternatives did not meet multiple criteria and were screened from further modeling and evaluation.

In addition to the design, cost and modeling information used to evaluate the preliminary alternatives, a limited environmental analysis of the impacts of the various alternatives was conducted. This included identification of the known HTW sites in the project area. It also included working with the state/ Federal agencies and the local tribes on a panel to identify the possible impacts of each alternative. It was this information that was utilized to identify the impacts and potential mitigation and associated costs of mitigation. Finally a limited investigation of the effect on the geomorphology of the Chehalis River by several of the structural alternatives was conducted. The conclusions from this investigation were utilized in Phase II to confirm that the tentatively preferred plan selected did not have any significant impacts.

Several of the preliminary alternatives had various configurations/ designs that had either been carried through from the previous feasibility studies or had been developed by the local sponsor previous to this study. Some of these designs were weighed against each other and eliminated from further study. Other configurations were judged to be more cost effective or engineeringly effective.

The following flowchart documents the procedure for this phase of the formulation. It identifies the alternatives, the screening against the project criteria and whether an alternative was carried forward to Phase 2.

ALTERNATIVES	SCREENING RESULTS	CARRY FORWARD?
Alternative ~~1~~ No Action	Alternative 1– Does not address 1, 2, 5, 6, 9	YES (NO ACTION)
Alternative ~~2~~ Skookumchuck Dam	Alternative 2– Alone it does not address 2, 6	YES
Alternative ~~3~~ 3 Flowway/ Excavation	Alternative 3– Meets all criteria	YES
Alternative ~~4~~ Levee Alternative	Alternative 4– Meets all criteria	YES
Alternative ~~5~~ Flow Restrictor Alternative	Alternative 5– Does not address 1, 2, 5, 6	NO
Alternative ~~6~~ Non-Structural Alternative	Alternative 6– Does not address 1, 2, 5, 6	NO
Alternative ~~7~~ Interagency Alternative	Alternative 7– Meets all criteria	YES

EVALUATION/SCREENING CRITERIA

ENGINEERING CRITERIA:

1) Reduce flood hazards in the project area to the maximum extent practicable
2) Decrease the transportation closures during flooding on Interstate Highway 5 and other critical transportation corridors to the maximum extent practicable.
3) Avoid increasing flood risks downstream from the project area.
4) Avoid decreasing any existing low flow benefits provided by Skookumchuck Dam.

ECONOMIC CRITERIA:

5) Reduce flood damage costs in the project area to the maximum extent practicable
6) Reduce transportation delay costs in the study area to the maximum extent practicable.
7) Be cost-effective for both construction and maintenance.

ENVIRONMENTAL CRITERIA:

8) Avoid adverse impacts to the aquatic environment to the extent practicable. Minimize and compensate for unavoidable adverse impacts to the aquatic environment.
9) Incorporate appropriate fish and wildlife habitat creation, enhancement, and restoration measures to the extent practicable.
10) Comply with all Federal, State, and local regulations, including environmental regulations

4.5.2 Phase 1: Results of Preliminary Alternatives Screening

Alternative 1 - No Action: The No Action Alternative would not reduce flood hazards in the project area, and would not meet Criterion 1; it would also do nothing to reduce flood-related transportation closures (Criterion 2). It would not reduce flood damage costs (Criterion 5), or transportation delay costs (Criterion 6). Under the No Action Alternative, flood damage would continue to cost the local economy an estimated $8.8 million annually, and flood damage costs would increase as the cost of living increases. The No Action Alternative clearly could not reasonably meet the project criteria; however, it was carried forward for comparative purposes.

Alternative 2 – Skookumchuck Dam Modifications: This alternative was subjected to detailed economic and feasibility review, although it was evident early in the study process that it could not reasonably meet the project criteria as a “stand-alone” alternative. Modifications to Skookumchuck Dam would provide some flood damage reduction to Bucoda and parts of Centralia, but not to other parts of the study area (specifically, the City of Chehalis) and therefore could not fully meet Criteria 1 and 5 (maximum reduction of damage and damage costs). This alternative would have no effect on flooding of I-5 and other transportation routes and therefore could not meet Criteria 2 and 6 (maximum reduction of transportation delay and delay costs).

However, the Skookumchuck Dam modifications could provide flood damage reduction for portions of the study area. This alternative could also provide protection from some potential downstream flooding impacts by delaying flood flows on the Skookumchuck River until Chehalis River peak flows have passed. Therefore, Alternative 2 was screened out as a stand-alone alternative, but evaluated the benefit of incorporating it into Alternatives 4 and 7. Skookumchuck Dam modifications are also a feature of Alternative 3. Skookumchuck Dam modifications were carried further into the evaluation as a component of those three alternatives. As part of this process, the four design variations were evaluated. The short tunnel with gates and rubber crest weir was further modified by replacing the rubber crest weir with slide gates and was the only design that proved to be feasible from an engineering standpoint.

Alternative 3 – Overbank Excavation and Flowway Bypass: As a result of the initial analysis, the Skookumchuck bypass, the Centralia Hospital bypass, and hump excavation components were dropped from this alternative. The Centralia overbank excavation and the SR-6 bypass were retained as components of Alternative 3. As noted earlier, modifications to Skookumchuck Dam (described in Alternative 2 above) would be included to provide flood damage reduction along the Skookumchuck River and reduce downstream effects.

Alternative 3 was then further evaluated based on the project criteria. The first stages of analysis indicated that this alternative met all of the project criteria. Hydraulic modeling demonstrated that Alternative 3 would reduce flood stages significantly within the study area; therefore, it met Criterion 1. Alternative 3 would provide 100-year flood protection for I-5 and significantly decrease the flooding of other transportation corridors (Criterion 2). With the inclusion of Skookumchuck Dam modifications, Alternative 3 would not result in any additional downstream flood risks (Criterion 3). Low flow benefits at Skookumchuck Dam would be maintained (Criterion 4). The screening indicated that the flood stage reductions would significantly reduce the flood damage costs (Criterion 5). Because flooding would be decreased on transportation corridors, transportation delay costs would be reduced (Criterion 6). Construction, operation, and maintenance appeared to be cost effective (Criterion 7).

With regard to Criterion 8, a number of environmental concerns and issues were raised about Alternative 3. For example, concerns raised by resource agencies included potential changes in sediment transport on the Chehalis River, changes in river geomorphology, effects on groundwater recharge, potential reduction in summer low flows, impacts on water quality, and loss of wetlands and riparian areas. This alternative appeared to have the potential for more than minimal environmental impacts. Additional studies would be needed to evaluate the alternative's impact on environmental resources. The SR-6 bypass would reconnect a portion of the historic floodplain to the Chehalis River and could be designed to maximize the environmental benefits of this reconnection (Criterion 9). Additional review would be necessary to determine compliance with all applicable rules and regulations (Criterion 10).

The screening indicated that this alternative was consistent with the project criteria, although there were issues that needed further investigation. Specifically, the economic benefits and environmental impacts warranted further review. This alternative was carried forward for further evaluation.

Alternative 4 – Setback Levees: The initial screening indicated that Alternative 4 would reduce flooding from the Chehalis River, Salzer Creek, Skookumchuck River and Dillenbaugh Creek and would significantly reduce the flood hazards in Chehalis and Centralia (Criterion 1). Alternative 4 would meet Criterion 2 by protecting I-5 from flooding and providing protection to other critical transportation corridors in and around Chehalis and Centralia. This alternative would slightly increase flood stages downstream of the project area, potentially not meeting Criterion 3. However, further evaluation determined that these downstream risks would not be significant. By incorporating modifications to Skookumchuck Dam into the alternative, the risk would be alleviated and no increase in downstream flood impacts would be experienced. Low-flow benefits of the Skookumchuck Dam would be maintained (Criterion 4). Alternative 4 would protect a significant portion of the existing residential and commercial infrastructure in Centralia and Chehalis area from flooding and protect I-5, thereby reducing flood damage costs and transportation delay costs (Criteria 5 and 6, respectively). The initial analysis indicated that Alternative 4 was cost-effective (Criterion 7).

With regard to Criterion 8, Alternative 4 could result in impacts to wetlands and riparian areas. The Skookumchuck Dam modifications could also result in adverse impacts to fish habitat and riparian areas along the Skookumchuck River, mainly between the dam and the first tributary downstream of the dam. The resource agencies raised questions about reductions in groundwater recharge, changes in sediment transport, channel self-maintenance, and channel stability. Additional evaluation of the alternative's impact on environmental resources would be needed. Although the levee alignment incorporated avoidance of environmental impacts within the design, additional adjustments to the levee alignment may further reduce adverse impacts to wetlands and riparian areas. Setting the alignment away from the river's edge may also allow opportunities for environmental restoration (Criterion 9). Finally, additional review would be necessary to determine compliance with all applicable rules and regulations (Criterion 10).

This alternative appeared to be consistent with the criteria, although there were issues that needed further investigation. Specifically, the economic benefits and environmental impacts warranted further review. This alternative was carried forward for further evaluation.

Alternative 5 – Flow Restrictors: Preliminary hydraulic modeling of flow restrictors showed that they would not significantly reduce flooding in the project area and that they could cause a relatively significant increase in the areal extent and depth of flooding upstream of the structures. Therefore, Alternative 5 could not reasonably meet Criterion 1. Because flow restrictors would not decrease the flooding to I-5 or other critical transportation corridors in or around Chehalis or Centralia, the alternative would not meet Criterion 2. Any of the design options of Alternative 5 would avoid increased flooding downstream as the purpose would be to store water during a flood (Criterion 3). Alternative 5 does not include any modifications to Skookumchuck Dam, so low flow benefits would not be affected (Criterion 4). The flow restrictors would not reduce flood stages and flood damages in the study area and would not meet Criterion 5. Alternative 5 would not decrease flooding to I-5 and the costs of transportation delay and would not meet Criterion 6. All design options of Alternative 5 had very high operational and maintenance costs because of the multiple structures and extensive area of coverage, and Criterion 7 would not be met. Although there may be short-term changes in sediment transport associated with installation of flow restrictors, this alternative would likely not have significant environmental impacts (Criterion 8). The flow restrictors have potential to create or enhance wetlands and create off-channel fish habitat, and would meet Criterion 9. Further investigation would be necessary to determine if this alternative would comply with all Federal, State, and local regulations (Criterion 10).

Although Alternative 5 met some of the project criteria, none of the design options could reasonably meet all of the criteria. Alternative 5 was therefore dropped from further evaluation.

Alternative 6 – Non-Structural Alternative: Alternative 6 would reduce some of the flood hazards in the study area by removing structures from the floodplain (Criterion 1) although it would not have any effect on closures of the existing transportation corridors (Criterion 2). Alternative 6 would not result in flooding impacts downstream of the study area (Criterion 3) or affect the low flow benefits of Skookumchuck Dam (Criterion 4). Alternative 6 would reduce flood damages (Criterion 5) but would not have any effect on reducing the costs of transportation delays (Criterion 6). The cost effectiveness of Alternative 6 was not fully evaluated because the initial screening showed that large-scale and relocation of residents and businesses would be cost prohibitive. For example, based on information provided by the City of Centralia (City of Centralia 1998) it has been estimated that as many as 3,000 structures could need to be removed from Centralia alone. Therefore, this alternative would not meet Criterion 7. With regard to Criterion 8, there would be at least temporary air quality, soil disturbance, hazardous waste, and water quality issues associated with the demolition and removal of structures, and substantial adverse impacts on the social fabric and economy of the area if large numbers of residents and businesses were required to relocate. These impacts would need further evaluation if the alternative were carried forward. Alternative 6 would have high potential for environmental restoration, including reforestation and reestablishment of wildlife corridor connectivity, and would meet Criterion 9. Further investigation would be necessary to determine if this alternative would comply with all Federal, State, and local regulations (Criterion 10).

Because Alternative 6 could not reasonably meet Criteria 2, 6, and 7, it was dropped from further investigation. However, many of the non-structural measures contained in this alternative could be incorporated into any recommended plan.

Alternative 7 – Interagency Committee Alternative: Alternative 7 combines several aspects of Alternatives 2 through 6 and therefore is a multiple-action alternative. Through discussion with the alternatives subcommittee, the subcommittee concurred with the Corps' findings regarding the use of flow restrictors (see discussion of Alternative 5) and excavation of the hump (see discussion of Alternative 3) and therefore dropped those measures from Alternative 7. However, the other actions remained as part of Alternative 7.

When structural measures are included, Alternative 7 would reduce flood hazards (Criterion 1) and decrease transportation closures (Criterion 2). Again, when structural measures are included, Alternative 7 would not result in downstream impacts (Criterion 3) or changes in the low-flow operation of Skookumchuck Dam (Criterion 4). Because flood hazards would be reduced, costs of flood damages would also be reduced (Criterion 5) as would the costs of transportation delay (Criterion 6). Costs of operation and maintenance would need to be further evaluated to determine if Criterion 7 could be met. With regard to Criterion 8, adverse environmental impacts such as loss of existing wetlands and riparian areas, corridor connectivity, and impacts to potential fish habitat would likely be similar to Alternatives 4 and 6 if all measures were implemented. Additional analysis would need to be done to evaluate the socioeconomic effects of development restrictions. Restoration opportunities would be similar to Alternatives 4 and 6 and inclusion of the SR-6 bypass would provide restoration opportunities described earlier for that component of Alternative 3 (Criterion 9). Further investigation would be necessary to determine if this alternative would comply with all Federal, State, and local regulations (Criterion 10).

This alternative appeared to be consistent with the criteria, although there were issues that needed further investigation. Specifically, the operation and maintenance costs and environmental impacts warranted further review. This alternative was carried forward for further evaluation.

Preliminary Alternatives Screening Summary: The conclusion of this process identified three alternatives that tentatively met all the project criteria; it also identified one alternative that could actually be a project feature for the other three alternatives. Consistent with NEPA requirements, the No Action Alternative (Alternative 1) was also carried forward for further evaluation. The three alternatives that were carried through to phase 2 are provided in table 4-2..

TABLE 4-2 ALTERNATIVES FOR PHASE 2 SCREENING

• Alternative 1 – No Action Alternative
• Alternative 3A – Centralia overbank excavation and Chehalis SR6 flow-way bypass (could be combined with the dam modification (Alt 2))
• Alternative 4 – Levee System (could be combined with the dam modification (Alt 2))
• Alternative 7 – Interagency Committee Alternative (combination of nonstructural and structural features including the dam modifications (Alt 2))
• Alternative 2 – While Skookumchuck Dam Modifications did not meet multiple criteria, it was found to provide significant hydraulic reductions in flood stages along the Skookumchuck River and in parts of the City of Centralia. For this reason it was carried forward for further modeling and evaluation as a component to be considered for implementation in combination with other alternatives.

4.6 Phase 2 – Formulation and Screening of Final Alternatives

A risk-based analysis as described in Section 2.2.6, was performed for each alternative to determine residual damages, net benefits and project performance. The intermediate array of alternatives is as described in Section 4.5.2 and are generally comprised of measures on both the Chehalis and Skookumchuck Rivers. The formulation and screening strategy was developed to determine economic viability of each measure that comprises an alternative. The strategy first determines the measure that maximizes net benefits, then incrementally adds measures that (1) are incrementally justified and (2) do not render the entire alternative unjustified. Each river, and the associated measures, was evaluated as initially as hydraulically separable elements. The measure that yielded the highest net benefit became the first added measure. The evaluation separated the Chehalis and the Skookumchuck elements, however the influence (damages reduced) of one on the other was captured jointly as well as incrementally. The Chehalis River measures were evaluated as the first element, as those measures had the potential for the largest damage reduction. The Skookumchuck Dam element was the first added element with other measures evaluated beyond the first add to determine if those measures were incrementally justified. The following paragraphs describe the risk based analysis (RBA) results for both damages reduced and project performance for each alternative.

4.7 Phase 2 – Description of Final Alternatives

In Phase 2, the initial alternatives carried forward from Phase 1 were further modified into multiple variations of each alternative. The Phase 2 modified alternatives were configured based on a common water surface profile from the hydraulic model. For example, the with-project water surface profile generated with each alternative for a particular hydrologic event was used to size that particular alternative. All alternatives used the 100-year frequency flow and the associated profile to define levee heights, bypass size, etc. The 100-year frequency was selected as the common event for Phase 2 economic screening and also to allow comparison of engineering performance to the FEMA certification criteria.

4.7.1 Phase 2: Alternative 2 – Skookumchuck Dam Modification Alternative

In phase 2, a HEC-FDA analysis was conducted for the Skookumchuck River floodplain that evaluated benefits of the modifications at Skookumchuck Dam. The results showed the dam reduced damages and provided a positive benefit to cost ratio. To optimize the configuration, the team configured and modeled a "lower" pool (477 elevation) to evaluate its costs and benefits. The lower pool option does not raise the pool by inflatable rubber weir as with other alternatives but focuses on the addition of an improved outlet structure. The variations on Alternative 2 that were evaluated in Phase 2 are listed below by the name of each variation. The configuration of each variation is described.

- ***ExSkDam:*** This configuration describes the existing Skookumchuck Dam that is not a flood controlled reservoir.
- ***SKDam1:*** This is the "lower dam" configuration that does not raise the pool (remains at 477 elevation) but improves the outlet structure (2.b.2 without pool raise); it has 11,000 acre-feet of flood control storage.
- ***SKDam2:*** This is the configuration described as Skookumchuck Dam Modification 2.b.2. This alternative has 20,000 acre-feet of flood control storage by raising the storage elevation to 492.

In this phase a new configuration of 2.b.2 was utilized. It incorporated a design for both 11,000 acre feet storage and 20,000 acre feet storage. The reconfigured Alternative 2B2 – Short Tunnel with Slide Gates would consist of constructing a short outlet works tunnel in the left abutment of the dam between the existing spillway and dam crest. An outlets works tower with slide gates would be built at the entrance to the new tunnel. The tunnel would discharge into the existing spillway chute, which would be modified to handle the full PMF flow. For the high flood storage pool option, 20,000 acre-feet, three steel bascule gates would be add to the top of the existing ogee spillway.

For the 11,000 acre-feet option, the existing overflow spillway would remain as it is with no control gates. For this case, the overflow spillway would have a total capacity of approximately 28,000 cfs. In order for the spillway to pass the full PMF flow of 32,500 cfs, the spillway chute entrance would have to be modified as was assumed in Alternative 2B1. Reference the Skookumchuck Dam Design Appendix (Appendix B) for additional details.

4.7.2 Phase 2: Alternative 3 – Overbank Excavation and Flowway Bypass Alternative

The study team modeled this alternative as a separable first element measure and also in combination with the Skookumchuck Dam Modification feature. This evaluation determined that the alternative, including the Chehalis bypass measures alone, did not provide sufficient damage reduction and subsequent net benefits to remain a viable stand-alone alternative. Therefore, a levee component was added around the Centralia Airport. The names used for the sub-alternatives of Alternative 3 in documentation of the Phase 2 screening are:

- ***Bypass/APLev:*** This configuration includes the Overbank Excavation and Flowway Modifications Alternative 3A with the addition of levee modification at Centralia-Chehalis Airport and Skookumchuck Dam Modification 2.b.2 with 20,000 acre feet of storage.

- ***Bypass/SkDam1:*** This configuration includes the Overbank Excavation and Flowway Modifications Alternative 3A plus Skookumchuck Dam Modification 2.b.2 with 11,000 acre feet of flood storage.

- ***Bypass/SkDam2:*** This configuration includes the Overbank Excavation and Flowway Modifications Alternative 3A plus Skookumchuck Dam Modification 2.b.2 with 20,000 acre of flood storage.

Another iteration of this alternative was added to the analysis process. This included adding the remainder of the Chehalis levee system to this alternative and modifying the configuration of the bypasses. This alternative combined elements of alternatives 3A, 2 and 4.

- ***Hybrid Plan - SkookDam1:*** This configuration included a modification to the bypass at Mellen Street and the SR6 bypass. Both overbank excavations were reduced in size from the original Alternative 3A configuration. And the berm in the floodplain was removed. In addition the Chehalis levee system was added to this alternative. The levee heights were adjusted for the difference in hydraulic stages due to the influence of the overbank excavation areas. This also included the 11,000 acre-foot Skookumchuck Dam.
- ***Hybrid Plan -SkookDam2:*** This included the Hybrid plan with the 20,000-acre foot dam.

4.7.3 Phase 2: Alternative 4 – Levee Alternative

The Chehalis and Skookumchuck levees were evaluated separately to determine if the flood reductions measures for each segment were individually justified. Modeling runs indicated that the levees reduced damages significantly and were economically justified.

Seven sub-alternatives of Alternative 4 were developed and evaluated in this phase. These alternative configurations are as follows:

- ***CheLev1:*** This configuration includes levees on the Chehalis River at the original design height including levees along the Chehalis River, Salzer Creek and Dillenbaugh Creek.
- ***CheLev2:*** This configuration includes the levees on the Chehalis River elevated an additional 1.5 feet to the FEMA 100-year performance height.
- ***CheLev1-SkDam1:*** This configuration includes levees on the Chehalis River at the original design height combined with 11,000 acre-foot Skookumchuck Dam Alternative.

- ***CheLev2-SkDam1:*** This configuration includes levees on the Chehalis River elevated an additional 1.5 feet to the FEMA 100-year performance height combined with 11,000 acre-foot Skookumchuck Dam Alternative.
- ***CheLev2-SkDam2:*** This configuration includes levees on the Chehalis River elevated an additional 1.5 feet to the FEMA 100-year performance height combined with the 20,000 acre-foot Skookumchuck Dam Alternative.
- ***Skook Levee:*** This configuration includes the Skookumchuck River levees alone.
- ***CheLev1-SkLev:*** This configuration includes levees on the Chehalis River at the original design height combined with Skookumchuck River levees
- ***CheLev2-SkLev:*** This configuration includes levees on the Chehalis River elevated an additional 1.5 feet to the FEMA 100-year performance height combined with Skookumchuck River levees.

Another set of iterations of this alternative was added to the analysis process. This included addition of SR6 bypass to the levee combination and reduction of the length of the Skookumchuck River levees (from approximately 4 miles to approximately 2 miles), in combination with the original Chehalis levees and the Skookumchuck dam. The following describes these additional alternatives:

- ***CheLev2- SR6-SkDam1:*** This configuration includes levees on the Chehalis River at a 100 year protection, the 11,000 acre foot Skookumchuck dam alternative and a modified 400 foot wide SR6 bypass.
- ***CheLev2 -SR6-SkDam2:*** This configuration includes the 100-year levees on the Chehalis River, a 20,000-acre foot Skookumchuck dam alternative and the modified SR6 bypass.
- ***CheLev2-SkDam1/SkLevee:*** This configuration includes the 100-year Chehalis levees, an 11,000 acre-foot Skookumchuck Dam and the addition of the Skookumchuck levees as a second added feature.
- ***CheLev2-SkDam2/SkLevee:*** This configuration includes the 100-year Chehalis levees, a 20,000 acre-foot Skookumchuck Dam and the addition of the Skookumchuck levees as a second added feature.

4.7.4 Phase 2: Alternative 7 – Interagency Alternative

Earlier hydraulic model runs showed that all the structural measures of Alternative 7 would need to be implemented in order to meet project criteria related to engineering effectiveness. This resulted in excessive costs that were not economically justified. In order to determine if this alternative could still be viable the team modified it to include levees and eliminated features such as flow restrictors and raising I-5 because they were too costly and did not provide substantial hydraulic benefits. Alternative 7 was reconfigured to included levees along I-5.

The resultant alternative configurations Alternative 7 that were evaluated during Phase 2 are as follows:

- ***Alternative 7:*** This alternative included all the structural features listed in the description of Alternative 7 (measures 12 through 17). The non-structural measures could not be modeled or costed out for the study. This alternative did not reduce damages to the highway or the buildings, therefore was not further evaluated.
- ***Alternative 7A Combo- SkookDam1:*** This configuration is the same as Alternative 7 above, but elevation of I-5 is not included and is replaced by implementation of levees along I-5. This alternative included a dam with 11,000-acre foot flood storage.
- ***Alternative 7A Combo- SkookDam2:*** This configuration is the same as Alternative 7 above, but elevation of I-5 is not included and is replaced by implementation of levees along I-5. This alternative included a dam with 20,000-acre feet of flood storage.

4.8 Phase 2 - Summary of Final Alternatives

Table 4-3 provides a summary list of the final alternatives to undergo phase two screening.

TABLE 4-3 FINAL ALTERNATIVES

ALTERNATIVE	CONFIGURATION	DESCRIPTION
Alternative 1		**No- Action Alternative**
Alternative 2		**Skookumchuck Dam Modifications Alternative**
	SKDam1	Dam modification alternative 2.b.2 without pool raise
	SKDam2	Dam modification alternative 2.b.2
	SKDam	Existing dam
Alternative 3		**Overbank Excavation and Flowway Bypass Alternative**
	Bypass – SkDam2	Bypass 3.a with dam modification alternative 2.b.2
	Bypass –SkDam1	Bypass 3.a with dam modification alternative 2.b.2 without pool raise
	Hybrid –SkDam1	Modified bypass with levee alternative with dam modification alternative 2.b.2 without pool raise
	Hybrid –SkDam2	Modified bypass with levee alternative with dam modification alternative 2.b.2 with pool raise
Alternative 4		**Levee System Alternative**
	CheLev2 - SkDam	Chehalis River, Salzer Creek, Dillenbaugh Creek modified levee design to 100-yr performance level with existing dam
	CheLev2 – SKDam1	Chehalis River, Salzer Creek, Dillenbaugh Creek levee design to 100- yr performance level with SKDam1
	CheLev2 – SKDam2	Chehalis River, Salzer Creek, Dillenbaugh Creek levee design to 100-yr performance level with SKDam2
	CheLev2-ExSkDam/SkLev	Chehalis River, Salzer Creek, Dillenbaugh Creek levee design to 100-yr performance level with existing dam and Skookumchuck levees
	CheLev2-SkDam1/SkLev	Chehalis River, Salzer Creek, Dillenbaugh Creek levee design to 100-yr performance level with SKDam1 and Skookumchuck Levees
	CheLev2-SkDam2/SkLev	Chehalis River, Salzer Creek, Dillenbaugh Creek levee design to 100-yr performance level with SKDam2 and Skookumchuck Levees
Alternative 7		**Interagency Alternative**
	Alternative 7- existing dam	All structural features without I-5 raise and with levees with existing dam
	Alternative 7- SkDam1	All structural features without I-5 raise and with levees with low pool dam
	Alternative 7- SkDam2	All structural features without I-5 raise and with levees with high pool dam

4.9 Phase 2 - Estimated Costs of Final Alternatives

Preliminary costs estimates developed during Phase 1 were refined for all final phase 2 alternatives. The cost estimates were developed to include: 1) Construction Costs, 2) Real Estate Costs, 3) Operation and Maintenance Costs, and 4) Mitigation Costs. These cost estimates are presented in Table 4-4 on the following page.

TABLE 4-4 SUMMARY COST ESTIMATES FOR FINAL ARRAY OF ALTERNATIVES

	ALTERNATIVES	First Cost of Alternative	O & M Costs (per year)	Real Estate Appraised Cost	Mitigation Costs	Interest During Construction	Total Costs w/o O&M	Total Annualized Costs
#2	**Skookumchuck Dam Modifications**							
	SkDam 1: This is the "lower dam" configuration that does not raise the pool (remains at 477 elevation) but improves the outlet structure (2.b.2 without pool raise); it has 11,000 acre-feet of flood control storage.	$6,034,053	$448,297	$0	$3,270,000	$569,873	**$9,873,926**	**$1,085,698**
	SkDam 2: This is the configuration described as Skookumchuck Dam Modification 2.b.2. This alternative has 20,000 acre-feet of flood control storage by raising the storage elevation to 492.	$8,237,016	$514,512	$0	$3,270,000	$704,805	**$12,211,821**	**$1,302,834**
#3	**Bypass**							
	Bypass w/o Dam: This configuration includes the Overbank Excavation and Flowway Modifications Alternative 3A.	$64,553,252	$37,100	$14,794,758	$8,713,900	$5,393,792	**$93,455,702**	**$6,070,038**
	Bypass - SkDam 1: This configuration includes the Overbank Excavation and Flowway Modifications Alternative 3A plus Skookumchuck Dam Modification 2.b.2 with 11,000 acre feet of flood storage.	$70,587,305	$448,297	$15,794,758	$11,983,900	$6,024,915	**$104,390,878**	**$7,187,144**
	Bypass - SkDam 2: This configuration includes the Overbank Excavation and Flowway Modifications Alternative 3A plus Skookumchuck Dam Modification 2.b.2 with 20,000 acre of flood storage.	$72,790,268	$551,612	$15,794,758	$11,983,900	$6,159,847	**$106,728,773**	**$7,441,379**
	Bypass - AP Levee- Skdam2 This configuration includes the Overbank Excavation and Flowway Modifications Alternative 3A with the addition of levee modification at Centralia-Chehalis Airport and Skookumchuck Dam Modification 2.b.2 with 20,000 acre feet of storage.)	$74,481,054	$551,612	$14,794,758	$8,713,900	$6,001,870	**$103,991,582**	**$7,264,683**
	Hybrid - SkDam1: This configuration included a modification to the bypass at Mellen Street and the SR6 bypass. Both overbank excavations were reduced in size from the original Alternative 3A configuration. And the berm in the floodplain was removed. In addition the Chehalis levee system was added to this alternative. The levee heights were adjusted for the difference in hydraulic stages due to the influence of the overbank excavation areas. This also included the 11,000 acre-foot Skookumchuck Dam.	$61,135,412	$547,789	$14,794,758	$8,713,900	$5,184,449	**$89,828,519**	**$6,346,578**
	Hybrid - SkDam2 (This included the Hybrid plan with the 20,000-acre foot dam)	$63,338,375	$1,099,401	$14,794,758	$8,713,900	$5,319,381	**$92,166,414**	**$7,049,110**

- continued next page -

	ALTERNATIVES	First Cost of Alternative	O & M Costs (per year)	Real Estate Appraised Cost	Mitigation Costs	Interest During Construction	Total Costs w/o O&M	Total Annualized Costs
#4	**Levee**							
	CheLev2: This configuration includes the levees on the Chehalis River elevated an additional 1.5 feet to the FEMA 100-year performance height.	$39,790,000	$99,492	$7,493,624	$8,713,900	$3,429,848	**$59,427,372**	**$3,935,766**
	CheLev2 - SkDam1: This configuration includes levees on the Chehalis River elevated an additional 1.5 feet to the FEMA 100-year performance height combined with Skookumchuck Dam Alternative.	$45,824,053	$547,789	$7,493,624	$11,983,900	$3,999,722	**$69,301,299**	**$5,021,464**
	CheLev2 - SkDam2: This configuration includes levees on the Chehalis River elevated an additional 1.5 feet to the FEMA 100-year performance height combined with the 20,000 acre-foot Skookumchuck Dam Alternative.	$48,027,016	$514,512	$7,493,624	$11,983,900	$4,134,653	**$71,639,193**	**$5,139,107**
	SR 6	$2,907,935	$10,000	$2,000,000	$0	$300,611	**$5,208,546**	**$346,232**
	CheLev2-SkDam1-SR6: (This configuration includes levees on the Chehalis River at a 100 year protection, the 11,000 acre foot Skookumchuck dam alternative and a modified 400 foot wide SR6 bypass)	$48,731,988	$557,789	$9,493,624	$11,983,900	$4,300,333	**$74,509,845**	**$5,367,696**
	CheLev2-SkDam2-SR6: (This configuration includes the 100-year levees on the Chehalis River, a 20,000-acre foot Skookumchuck dam alternative and the modified SR6 bypass)	$50,934,951	$624,004	$9,493,624	$11,983,900	$4,435,264	**$76,847,739**	**$5,584,832**
	Skooklevee - 100 year: This configuration includes the Skookumchuck River levees alone.	$10,360,000	$19,025	$2,802,000	$0	$806,173	**$13,968,173**	**$920,726**
	Skooklevee - Chehalis Backwater: This shows the cost of the Skookumchuck River Levees that are attributable to the Chehalis levees to mitigate against all backwater stage increases.	$5,560,000	$19,025	$2,802,000	$0	$512,173	**$8,874,173**	**$591,888**
	CheLev2-SkDam1-Skooklevee: This configuration includes the 100-year Chehalis levees, an 11,000 acre-foot Skookumchuck Dam and the addition of the Skookumchuck levees as a second added feature.	$56,184,053	$566,814	$10,295,624	$11,983,900	$4,805,894	**$83,269,471**	**$5,942,190**
	CheLev2-SkDam1-Skooklevee-SR6: This configuration includes levees on the Chehalis River at a 100 year protection, the 11,000 acre foot Skookumchuck dam alternative and a modified 400 foot wide SR6 bypass.	$59,091,988	$576,814	$12,295,624	$11,983,900	$5,106,505	**$88,478,017**	**$6,288,422**
#7	**Interagency Committee Alternative - Modified**						**$0**	
	Alternative 7A Combo- SkookDam1: This configuration is the same as Alternative 7 above, but elevation of I-5 is not included and is replaced by implementation of levees along I-5. This alternative included a dam with 11,000-acre foot flood storage.	$55,336,224	$251,080	$12,493,624	$11,983,900	$4,888,592	**$84,702,340**	**$5,718,953**

4.10 Phase 2- Risk-Based Assessment and Evaluation of Final Alternatives

The following paragraphs describe the RBA results for damages reduced for each measure and combination of alternatives. The analysis results and screening logic are described below.

4.10.1 With Project Hydrology and Hydraulics

The with project conditions for each measure were modeled by modifying the existing condition input data according to the results of the UNET modeling results. For example, if a particular discharge-frequency or stage-discharge function was altered as a result of a particular measure (levee, bypass, or reservoir), the appropriate without project data set was modified and HEC-FDA recalculated residual damages and performance parameters. Total residual damages for each alternative were determined by coupling measures for each of the Chehalis River and the Skookumchuck River. For example, one alternative is comprised of levees on the Chehalis and levees on the Skookumchuck. The full array of intermediate alternatives is described in Section 4.7.

4.10.2 Residual Damages, Damages Reduced and Net Benefits

The Chehalis River Levee measures, as the first alternative element, were evaluated using the existing Skookumchuck Dam operation. The HEC-FDA results for residual damages are presented in Table 4-5. Table 4-5's Other Damages Reduced includes transportation delays, agricultural damages, and the avoided cost savings from eliminating raising I-5 during its scheduled modification as described in Section 6.3. Table 4-5 indicates that only three of the five general alternative plans presented in the table have a likelihood of meeting NED criteria. These three general plans are; (1) CheLev2, (2) Hybrid Plan, and (3) CheLev2 – SKLev (in Table 40 nomenclature). Each of these general plans may or may not contain a Skookumchuck Dam modification. The two general plan types that can be ruled out as potentially producing a NED candidate are Bypass and Alternative 7. These two general plan types are ruled out for further analyses by their negative net NED benefits showing at this level of plan formulation. The Hybrid Plan general plan type is also eliminated from further analyses at this time given the disparity in net NED benefits in comparison to the other two general plan types. Although the

Hybrid Plan type shows positive net NED benefits, it is unlikely that this plan type could close the annual benefit difference of $324, given the level of feature overlap between the general plan types.

The general plan type with the highest net benefit is ChevLev2 with a net annual benefit range $1,677 to $2,699. With the difference between the two remaining general plan types being only levees on the Skookumchuck River and that the general plan type with these levees (ChevLev2 – SKLev) showing incremental justification of the Skookumchuck levees, the remaining analyses will focus on this general plan type.

The Skookumchuck Dam was included in the evaluation as a first added element to determine the flood reduction effectiveness. There were two storage alternatives evaluated an 11K acre-foot dam and a 20K acre-foot dam. Each storage component was evaluated for each of the Chehalis plans. The incremental benefit for the CheLev2 plan with the 11K Dam is $2,107 with an incremental B/C of 1.94. The combined plan yields net benefit of $2,698.64 with a B/C of 1.48. This includes the impacts of the dam on the Chehalis since the effects are captured in the resultant hydraulic analysis. The incremental benefit for raising the CheLev2 plan from 11K to the 20K Dam is $122 with an incremental cost of $217, an incremental B/C of 0.56. Increasing the dam size from 11K to 20K is not justified and for this reason the analysis assumes that the 11K dam is incrementally justified as the first added element.

In an attempt to further reduce flooding on the Skookumchuck River, specifically in Reach 4, levees along the Skookumchuck River were analyzed. The incremental net benefit change from CheLev2 plan with the 11K Dam to the CheLev2 plan with the 11K Dam and Skookumchuck levees is -$6; and given that the ChevLev2 with 11K Dam alternative does not consider backwater effects on the Skookumchuck River at this stage, it is reasonable to assume that the CheLev2 – SKDam & SKLev plan type would most likely generate the NED recommended plan.

TABLE 4-5 WITH PROJECT ECONOMIC ANALYSIS

Alternative	Expected Annual Damages ($1,000)*					Flood Damages Reduced	Other Damages**	Other Damages Reduced	Total Damages Reduced	Cost	Net Benefit	B/C
	Chehalis		Skookumchuck		Total							
	Res/Comm	Public	Res/Comm	Public								
No Action	6147.81	442.93	2211.84	42.36	8844.94	0.00	2239.10	0.00	0.00	0.00	0.00	0.00
CheLev2 - Exsting SkDam	2347.19	82.95	2392.52	46.94	4869.60	3975.34	2239.10	2239.10	6214.44	4537.06	1677.38	1.37
CheLev2 - SkDam 1	2081.67	70.05	595.59	15.34	2762.65	6082.29	2239.10	2239.10	8321.39	5622.75	2698.64	1.48
CheLev2 - SkDam 2	2057.19	68.37	504.68	10.57	2640.81	6204.13	2239.10	2239.10	8443.23	5839.89	2603.34	1.45
CheLev2SR6 - Ex SkDam	2186.09	58.63	2290.11	42.72	4577.55	4267.39	2239.10	2239.10	6506.49	4863.89	1642.60	1.34
CheLev2SR6 - SkDam 1	1893.35	45.85	694.59	14.09	2647.88	6197.06	2239.10	2239.10	8436.16	5949.58	2486.58	1.42
CheLev2SR6 - SkDam 2	1876.98	43.86	498.56	10.30	2429.70	6415.24	2239.10	2239.10	8654.34	6166.72	2487.62	1.40
Hybrid Plan - Existing Dam	2231.15	61.06	1363.55	38.16	3693.92	5151.02	2239.10	2239.10	7390.12	5098.44	2291.68	1.45
Hybrid Plan - SkDam 1	1901.64	47.66	562.03	14.14	2525.47	6319.47	2239.10	2239.10	8558.57	6184.14	2374.43	1.38
Hybrid Plan - SkDam 2	1900.60	45.02	464.71	8.85	2419.18	6425.76	2239.10	2239.10	8664.86	6401.28	2263.58	1.35
CheLev2 - Ex SkDam/SKLev	2217.91	60.56	1677.61	42.06	3998.14	4846.80	2239.10	2239.10	7085.90	4865.90	2220.00	1.46
CheLev2 - SkDam 1/SkLev	1932.99	50.86	453.78	11.19	2448.82	6396.12	2239.10	2239.10	8635.22	5951.60	2683.62	1.45
CheLev2 - SkDam 2/SkLev	1924.27	48.05	337.42	9.32	2319.06	6525.88	2239.10	2239.10	8764.98	6168.73	2596.25	1.42
Bypass - Existing Dam	3404.44	30.56	2225.90	38.25	5699.15	3145.79	2239.10	0.00	3145.79	6070.04	-2924.25	0.52
Bypass - SkDam 1	2996.60	98.17	542.00	9.28	3646.05	5198.89	2239.10	0.00	5198.89	6882.46	-1683.57	0.76
Bypass - SkDam 2	2977.01	94.28	458.70	6.60	3536.59	5308.35	2239.10	0.00	5308.35	7526.87	-2218.52	0.71
Alternative 7 - Existing Dam	3382.07	97.10	2288.89	41.94	5810.00	3034.94	2239.10	0.00	3034.94	5081.55	-2046.61	0.60
Alternative 7 - SkDam 1	2899.76	74.89	601.44	18.63	3594.72	5250.22	2239.10	0.00	5250.22	5718.95	-468.73	0.92
Alternative 7 - SkDam 2	2869.41	70.80	526.26	7.69	3474.16	5370.78	2239.10	0.00	5370.78	5869.87	-499.09	0.91

** Numbers may not add due to rounding* ***Other Damages includes 1-5 avoided cost savings and traffic delay reductions through 2012.*

4.10.3 Project Performance

In addition to the economic basis for screening alternatives, the engineering performance is also considered. The two performance indices targeted for this analysis were the Expected Annual Exceedance and the Conditional Probability of Non-Exceedance for the .01 event. A goal of selected alternative would be to provide certification to FEMA for providing protection against a 100 – year flood event. The reporting of the performance is based on the controlling value at any of the index locations for each river. The table below details the expected exceedance, the conditional probability of non-exceedance and the equivalent long-term risk.

TABLE 4-6 PHASE 2 PERFORMANCE ANALYSIS

Alternative	Expected Annual Exceedance %		Equivalent Long-Term Risk						Conditional Probability of Design Containing Indicated Event							
			10 Yrs		25 Yrs		50 Yrs		10%		4%		2%		1%	
	Chehalis	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook
New Existing	59.6	21.1	100.0	90.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CheLev2 - Exsting SkDam	0.3	21.1	2.7	90.4	6.7	99.7	12.9	100.0	100.0	6.3	100.0	0.2	99.7	0.1	95.7	0.0
CheLev2 - SkDam 1	0.3	5.5	2.5	43.3	6.1	75.8	11.2	94.1	100.0	87.6	100.0	48.6	99.7	4.2	95.9	0.1
CheLev2 - SkDam 2	0.2	5.5	2.4	43.3	6.0	75.3	11.6	94.1	100.0	87.5	100.0	48.2	99.7	4.1	96.3	0.6
CheLev2SR6 - Ex SkDam	0.2	21.1	2.0	90.6	4.9	99.7	9.5	100.0	100.0	6.4	100.0	0.2	99.7	0.0	97.3	0.0
CheLev2SR6 - SkDam 1	0.2	5.4	1.7	42.7	4.3	75.2	8.3	93.8	100.0	87.8	100.0	51.8	99.8	3.3	98.1	0.1
CheLev2SR6 - SkDam 2	0.2	5.4	1.7	42.4	4.1	74.8	8.1	93.7	100.0	87.7	100.0	52.4	99.8	4.3	98.2	0.5
Hybrid Plan - Existing Dam	0.3	20.5	2.7	89.9	6.7	99.7	12.9	100.0	100.0	7.5	100.0	0.2	99.7	0.1	96.0	0.0
Hybrid Plan - SkDam 1	0.2	2.4	2.4	50.4	6.0	82.6	11.6	97.0	100.0	79.1	100.0	37.6	99.8	3.7	97.5	0.1
Hybrid Plan - SkDam 2	0.2	6.8	2.4	50.4	5.8	82.7	11.3	97.0	100.0	79.1	100.0	37.6	99.7	3.8	97.4	0.6
CheLev2 - Ex SkDam/SKLev	0.2	21.0	2.2	90.5	5.4	99.7	10.6	100.0	100.0	6.4	100.0	0.2	99.6	0.0	96.9	0.0
CheLev2 - SkDam 1/SkLev	0.2	6.7	2.1	50.1	5.1	82.4	9.9	96.9	100.0	80.6	100.0	35.7	99.6	3.7	96.9	0.1
CheLev2 - SkDam 2/SkLev	0.2	6.7	1.7	50.1	4.6	82.4	9.0	96.9	100.0	80.6	100.0	35.7	99.8	3.6	97.8	0.7
Bypass - Existing Dam	49.2	21.0	99.9	90.5	100.0	99.7	100.0	100.0	0.0	6.4	0.0	0.2	0.0	0.0	0.0	0.0
Bypass - SkDam 1	49.2	6.7	99.9	49.8	100.0	82.2	100.0	96.8	0.0	80.2	0.0	38.1	0.0	3.4	0.0	0.2
Bypass - SkDam 2	49.3	6.6	99.9	49.5	100.0	81.9	100.0	96.7	0.0	80.2	0.0	38.5	0.0	4.1	0.0	0.6
Alternative 7 - Existing Dam	53.0	21.1	100.0	90.6	100.0	99.7	100.0	100.0	0.0	6.3	0.0	0.2	0.0	0.0	0.0	0.0
Alternative 7 - SkDam 1	52.0	6.8	99.9	50.5	100.0	82.7	100.0	97.0	0.0	80.1	0.0	34.0	0.0	3.6	0.0	0.1
Alternative 7 - SkDam 2	52.0	6.8	99.9	50.4	100.0	82.7	100.0	97.0	0.0	80.1	0.0	34.0	0.0	3.7	0.0	0.7

4.11 Phase 2 - Screening Results, Preliminary NED Alternative

Based on economic performance and engineering performance evaluated in screening Phase 2, the most effective alternative for reducing flood damages was identified as a combination of the flood control features Chehalis Levee 2 and Skookumchuck Dam 1. This alternative produced the highest net benefits. The alternative producing the next highest level of net benefits was Chehalis Levee 2, Skookumchuck Dam 1, and Skookumchuck Levees. Because the net benefits of the two alternatives were very close, all three features were carried forward to the next iteration of plan formulation, *Phase 3 - Optimization*

At this time, no plan satisfies FEMA's Conditional Non-Exceedance Probability criteria for both rivers. However, the Chehalis Levee 2 Plan alternative meets the 0.01 Conditional Non-Exceedance Probability for the Chehalis River along the protected areas. To achieve the same performance along the Skookumchuck River, it appears that additional levees will need to be included along with a dam measure.

4.12 Phase 3 – Optimization and Identification of NED Plan

In the final phase of plan formulation, several different sizes of the plan features carried over from phase 2 were further evaluated for optimization of project size. This optimization resulted in identification of the NED plan.

4.12.1 Optimization

The array of alternatives analyzed in this optimization phase consists of three basic features that are as follows.

- Skookumchuck Dam Modification
- Chehalis River Levee Improvements, and
- Skookumchuck River Levee Improvements

Each of these basic features has an array of its own. For Skookumchuck Dam, two storage capacity level increases were considered with these capacity increases being,

- An 11,000 acre-foot increase
- A 20,000 acre-foot increase.

For the Chehalis and Skookumchuck Rivers' five levee improvement level are considered for each with these levels being[5],

- A levee height one foot below the 100-yr water surface elevation (WSE)[6]
- A levee height at the 100-yr WSE
- A levee height that has a 75-yr level of flood protection
- A levee height that has a 100-yr level of flood protection
- A levee height of approximately 200-yr level of protection, and
- A backwater levee only option on the Skookumchuck River.

These basic modes were combined to form 52 potential alternatives, as shown in Table 4-6, below.

[5] Additionally, a levee height at two feet below the 100-yr WSE was evaluated on the Skookumchuck River as explained in the paragraph following Table 4-9, later in this section.
[6] As the study is conducted under a risk-based approach, the "100-yr" flood consists of a distribution of floods defined by risk-based parameters as presented in hydraulics and hydrology appendices. For the 100-yr WSE, the mean values of the risk parameters associated with the 1% chance flood were utilized to develop the water surface elevation. To provide protection of a given frequency, and as a flood of a given frequency consists of many differing levels, the height of the levee must contain 90% of that level's distribution of floods (100-yr WSE + 3 feet).

TABLE 4-6 PHASE III ALTERNATIVES

Skookumchuck Dam	Chehalis Levee	Skookumchuck Levee
Existing	100	Backwater
11,000	100	Backwater
11,000	WSE -1	WSE -1
11,000	WSE -1	WSE
11,000	WSE -1	200
11,000	WSE -1	100
11,000	WSE -1	75
11,000	WSE	WSE -1
11,000	WSE	WSE
11,000	WSE	200
11,000	WSE	100
11,000	WSE	75
11,000	75	WSE -1
11,000	75	WSE
11,000	75	200
11,000	75	100
11,000	75	75
11,000	100	WSE -1
11,000	100	WSE
11,000	100	200
11,000	100	100
11,000	100	75
11,000	200	WSE -1
11,000	200	WSE
11,000	200	200
11,000	200	100
11,000	200	75
20,000	WSE -1	WSE -1
20,000	WSE -1	WSE
20,000	WSE -1	200
20,000	WSE -1	100
20,000	WSE -1	75
20,000	WSE	WSE -1
20,000	WSE	WSE
20,000	WSE	200
20,000	WSE	100
20,000	WSE	75
20,000	75	WSE -1
20,000	75	WSE
20,000	75	200
20,000	75	100
20,000	75	75
20,000	100	WSE -1
20,000	100	WSE
20,000	100	200
20,000	100	100
20,000	100	75
20,000	200	WSE -1
20,000	200	WSE
20,000	200	200
20,000	200	100
20,000	200	75

The HEC-FDA model was employed to determine residual damages for all damages except for those damages related to agriculture and transportation. In the case of agricultural damages, the designs of the alternatives would not afford protection to the Chehalis River's west side in the area of agricultural production and agricultural damage reductions would be minimal, if at all. Therefore, no agricultural damage reductions are claimed for any alternative. In the case of rail freight transportation damages the proposed alternatives would not fully cover the potentially impacted rail lines and transportation delays would continue during flooding events; therefore, no damage reductions are claimed.

In the without-project condition traffic on Interstate-5 experiences delays during flood events. I-5 is scheduled to have major modifications made by 2012 to increase its capacity and to eliminate flood related delays. The without-project analysis indicates that the annual damages associated with traffic delays on I-5 are $476,300. Full implementation of flood control operations for all alternatives is 2007. Applying a net present value approach to the expected annual traffic delay costs during the 2007 to 2012 timeframe yields an annual damage reduction of $129,079, if implemented.

Currently there are plans to upgrade and modernize I-5 to increase its capacity and remove it from the threat of flooding. The current cost of this future modernization for elevating the roadway above the 100-yr event is estimated at $44,000,000. The plan for I-5 indicates that implementation would take place after the base year of any of the alternatives and would be finished in 2012. If an alternative with at least a 100-yr level of protection is implemented, modernization of I-5 would avoid the elevation expenditure of $44,000,000. As this expenditure would occur in the future after the construction of an alternative, discounting this future cost yields a current base year value of $32,686,200. Amortization of this avoided expenditure yields an annual savings of $2,110,000.

NED benefits for the alternatives are shown in Table 4-7, below.

TABLE 4-7 PHASE III ALTERNATIVES NED BENEFITS

(in $1,000s, 2002 price level)

Skookumchuck Dam	Chehalis Levee	Skookumchuck Levee	Residual Damages*	Damage Reduction	I-5 Avoided Costs	I-5 Delay Benefits	Total Benefits
No Action	100	Backwater	4577.55	4267.37	2110.00	129.10	6,506.47
11,000	100	Backwater	2647.88	6197.04	2110.00	129.10	8,436.14
11,000	WSE -1	WSE -1	4340.59	4504.33	0.00	0.00	4504.33
11,000	WSE -1	WSE	4320.37	4524.55	0.00	0.00	4524.55
11,000	WSE -1	75	4305.28	4539.64	0.00	0.00	4539.64
11,000	WSE -1	100	4256.03	4588.89	0.00	0.00	4588.89
11,000	WSE -1	200	4213.24	4631.68	0.00	0.00	4631.68
20,000	WSE -1	WSE -1	4179.64	4665.28	0.00	0.00	4665.28
20,000	WSE -1	WSE	4157.31	4687.61	0.00	0.00	4687.61
20,000	WSE -1	75	4142.48	4702.44	0.00	0.00	4702.44
20,000	WSE -1	100	4087.72	4757.2	0.00	0.00	4757.20
20,000	WSE -1	200	4060.17	4784.75	0.00	0.00	4784.75
11,000	WSE	WSE -1	3695.48	5149.44	0.00	0.00	5149.44
11,000	WSE	WSE	3675.26	5169.66	0.00	0.00	5169.66
11,000	WSE	75	3660.17	5184.75	0.00	0.00	5184.75
11,000	WSE	100	3610.93	5233.99	0.00	0.00	5233.99
11,000	WSE	200	3568.13	5276.79	0.00	0.00	5276.79
20,000	WSE	WSE -1	3540.11	5304.81	0.00	0.00	5304.81
20,000	WSE	WSE	3517.77	5327.15	0.00	0.00	5327.15
20,000	WSE	75	3502.94	5341.98	0.00	0.00	5341.98
20,000	WSE	100	3448.18	5396.74	0.00	0.00	5396.74
20,000	WSE	200	3420.63	5424.29	0.00	0.00	5424.29
11,000	75	WSE -1	2983.3	5861.62	0.00	0.00	5861.62
11,000	75	WSE	2963.1	5881.82	0.00	0.00	5881.82
11,000	75	75	2948	5896.92	0.00	0.00	5896.92
11,000	75	100	2898.76	5946.16	0.00	0.00	5946.16
11,000	75	200	2855.97	5988.95	0.00	0.00	5988.95
20,000	75	WSE -1	2846.42	5998.5	0.00	0.00	5998.50
20,000	75	WSE	2824.1	6020.82	0.00	0.00	6020.82
20,000	75	75	2809.27	6035.65	0.00	0.00	6035.65
20,000	75	100	2754.5	6090.42	0.00	0.00	6090.42
20,000	75	200	2726.94	6117.98	0.00	0.00	6117.98
11,000	100	WSE -1	2533.37	6311.55	2110.00	129.10	8,550.65
11,000	100	WSE	2513.16	6331.76	2110.00	129.10	8,570.86
11,000	100	75	2498.06	6346.86	2110.00	129.10	8,585.96
11,000	100	100	2448.83	6396.09	2110.00	129.10	8,635.19
20,000	100	WSE -1	2409.98	6434.94	2110.00	129.10	8,674.04
11,000	100	200	2406.04	6438.88	2110.00	129.10	8,677.98
20,000	100	WSE	2388.65	6456.27	2110.00	129.10	8,695.37
20,000	100	75	2373.82	6471.1	2110.00	129.10	8,710.20
11,000	200	WSE -1	2337.05	6507.87	2110.00	129.10	8,746.97
20,000	100	100	2319.05	6525.87	2110.00	129.10	8,764.97
11,000	200	WSE	2316.83	6528.09	2110.00	129.10	8,767.19
11,000	200	75	2301.74	6543.18	2110.00	129.10	8,782.28
20,000	100	200	2291.5	6553.42	2110.00	129.10	8,792.52
11,000	200	100	2252.5	6592.42	2110.00	129.10	8,831.52
20,000	200	WSE -1	2223	6621.92	2110.00	129.10	8,861.02
11,000	200	200	2209.71	6635.21	2110.00	129.10	8,874.31
20,000	200	WSE	2200.67	6644.25	2110.00	129.10	8,883.35
20,000	200	75	2185.85	6659.07	2110.00	129.10	8,898.17
20,000	200	100	2131.07	6713.85	2110.00	129.10	8,952.95
20,000	200	200	2103.52	6741.4	2110.00	129.10	8,980.50

***Residual damages in this table do not include agriculture damages and rail damages – both these categories are not affected by proposed alternatives. Residual annual damages in these categories are $115,850 for agriculture and $32,200 for rail.*

Construction and annual costs for the various components are shown below in Table 4-8.

TABLE 4-8 COMPONENT COSTS

(in $1,000s, 2002 price level)

ALTERNATIVE	Total Construction Cost*	IDC	Total Economic Cost	Annualized Cost	O&M	TOTAL ANNUAL COST
Skookumchuck Dam						
Skookumchuck Dam 11,000 ac-ft	$9,304.05	$569.87	$9,873.93	$637.40	$448.30	$1,085.70
Skookumchuck Dam 20,000 ac-ft	$11,507.02	$704.80	$12,211.82	$788.32	$514.51	$1,302.83
Skookumchuck Levee						
Backwater	$8,362.00	$512.17	$8,874.17	$572.86	$19.03	$591.89
100yr WSE -1	$9,402.00	$575.87	$9,977.87	$644.11	$19.03	$663.14
100yr WSE	$10,102.00	$618.75	$10,720.75	$692.07	$19.03	$711.09
75yr Protection	$10,952.00	$670.81	$11,622.81	$750.30	$19.03	$769.32
100yr Protection	$13,162.00	$806.17	$13,968.17	$901.70	$19.03	$920.73
200yr Protection	$14,482.00	$887.02	$15,369.02	$992.13	$19.03	$1,011.16
Chehalis Levee						
100yr WSE -1	$48,155.46	$2,949.52	$51,104.98	$3,299.03	$99.49	$3,398.52
100yr WSE	$50,705.46	$3,105.71	$53,811.17	$3,473.73	$99.49	$3,573.22
75yr Protection	$53,675.46	$3,287.62	$56,963.08	$3,677.19	$99.49	$3,776.69
100yr Protection	$60,905.46	$3,730.46	$64,635.92	$4,172.51	$99.49	$4,272.00
200yr Protection	$64,975.46	$3,979.75	$68,955.21	$4,451.33	$99.49	$4,550.83

**includes Real Estate*

These components in combination form the alternatives and have total costs and net benefits as shown in Table 4-9, below.

TABLE 4-9 TOTAL ANNUAL COSTS AND NED NET BENEFITS PHASE III ALTERNATIVES

(in $1,000s, 2002 price level)

Dam Size	Chehalis Levee*	Skookumchuck Levee*	Residual Damages**	Damage Reduction	I-5 Avoided Costs	I-5 Delay Benefits	Total Benefits	Skook Dam Cost	Chehalis Levee Cost	Skook Levee Cost	Total Cost	Net Benefits
11	100	-1	$2,533.37	$6,311.55	$2,110.00	$129.10	$8,550.65	$1,085.70	$4,272.00	$663.14	$6,020.83	$2,529.82
11	100	0	$2,513.16	$6,331.76	$2,110.00	$129.10	$8,570.86	$1,085.70	$4,272.00	$711.09	$6,068.79	$2,502.07
11	100	BW	$2,647.88	$6,197.04	$2,110.00	$129.10	$8,436.14	$1,085.70	$4,272.00	$591.89	$5,949.58	$2,486.56
11	100	75	$2,498.06	$6,346.86	$2,110.00	$129.10	$8,585.96	$1,085.70	$4,272.00	$769.32	$6,127.02	$2,458.94
11	200	-1	$2,337.05	$6,507.87	$2,110.00	$129.10	$8,746.97	$1,085.70	$4,550.83	$663.14	$6,299.66	$2,447.31
20	100	-1	$2,409.98	$6,434.94	$2,110.00	$129.10	$8,674.04	$1,302.83	$4,272.00	$663.14	$6,237.97	$2,436.07
11	200	0	$2,316.83	$6,528.09	$2,110.00	$129.10	$8,767.19	$1,085.70	$4,550.83	$711.09	$6,347.62	$2,419.57
20	100	0	$2,388.65	$6,456.27	$2,110.00	$129.10	$8,695.37	$1,302.83	$4,272.00	$711.09	$6,285.92	$2,409.45
11	200	75	$2,301.74	$6,543.18	$2,110.00	$129.10	$8,782.28	$1,085.70	$4,550.83	$769.32	$6,405.85	$2,376.43
20	100	75	$2,373.82	$6,471.10	$2,110.00	$129.10	$8,710.20	$1,302.83	$4,272.00	$769.32	$6,344.16	$2,366.04
11	100	100	$2,448.83	$6,396.09	$2,110.00	$129.10	$8,635.19	$1,085.70	$4,272.00	$920.73	$6,278.42	$2,356.77
20	200	-1	$2,223.00	$6,621.92	$2,110.00	$129.10	$8,861.02	$1,302.83	$4,550.83	$663.14	$6,516.80	$2,344.22
20	200	0	$2,200.67	$6,644.25	$2,110.00	$129.10	$8,883.35	$1,302.83	$4,550.83	$711.09	$6,564.75	$2,318.60
11	100	200	$2,406.04	$6,438.88	$2,110.00	$129.10	$8,677.98	$1,085.70	$4,272.00	$1,011.16	$6,368.85	$2,309.13
20	200	75	$2,185.85	$6,659.07	$2,110.00	$129.10	$8,898.17	$1,302.83	$4,550.83	$769.32	$6,622.98	$2,275.19
11	200	100	$2,252.50	$6,592.42	$2,110.00	$129.10	$8,831.52	$1,085.70	$4,550.83	$920.73	$6,557.25	$2,274.27
20	100	100	$2,319.05	$6,525.87	$2,110.00	$129.10	$8,764.97	$1,302.83	$4,272.00	$920.73	$6,495.56	$2,269.41
11	200	200	$2,209.71	$6,635.21	$2,110.00	$129.10	$8,874.31	$1,085.70	$4,550.83	$1,011.16	$6,647.68	$2,226.63
20	100	200	$2,291.50	$6,553.42	$2,110.00	$129.10	$8,792.52	$1,302.83	$4,272.00	$1,011.16	$6,585.99	$2,206.53
20	200	100	$2,131.07	$6,713.85	$2,110.00	$129.10	$8,952.95	$1,302.83	$4,550.83	$920.73	$6,774.38	$2,178.57
20	200	200	$2,103.52	$6,741.40	$2,110.00	$129.10	$8,980.50	$1,302.83	$4,550.83	$1,011.16	$6,864.82	$2,115.68
Ext	100	BW	$4,577.55	$4,267.37	$2,110.00	$129.10	$6,506.47	$0.00	$4,272.00	$591.89	$4,863.89	$1,642.58
11	75	-1	$2,983.30	$5,861.62	$0.00	$0.00	$5,861.62	$1,085.70	$3,776.69	$663.14	$5,525.52	$336.10
11	75	0	$2,963.10	$5,881.82	$0.00	$0.00	$5,881.82	$1,085.70	$3,776.69	$711.09	$5,573.48	$308.34
11	75	75	$2,948.00	$5,896.92	$0.00	$0.00	$5,896.92	$1,085.70	$3,776.69	$769.32	$5,631.71	$265.21
20	75	-1	$2,846.42	$5,998.50	$0.00	$0.00	$5,998.50	$1,302.83	$3,776.69	$663.14	$5,742.66	$255.84
20	75	0	$2,824.10	$6,020.82	$0.00	$0.00	$6,020.82	$1,302.83	$3,776.69	$711.09	$5,790.61	$230.21

Dam Size	Chehalis Levee*	Skookumchuck Levee*	Residual Damages**	Damage Reduction	I-5 Avoided Costs	I-5 Delay Benefits	Total Benefits	Skook Dam Cost	Chehalis Levee Cost	Skook Levee Cost	Total Cost	Net Benefits
20	75	75	$2,809.27	$6,035.65	$0.00	$0.00	$6,035.65	$1,302.83	$3,776.69	$769.32	$5,848.84	$186.81
11	75	100	$2,898.76	$5,946.16	$0.00	$0.00	$5,946.16	$1,085.70	$3,776.69	$920.73	$5,783.11	$163.05
11	75	200	$2,855.97	$5,988.95	$0.00	$0.00	$5,988.95	$1,085.70	$3,776.69	$1,011.16	$5,873.54	$115.41
20	75	100	$2,754.50	$6,090.42	$0.00	$0.00	$6,090.42	$1,302.83	$3,776.69	$920.73	$6,000.25	$90.17
20	75	200	$2,726.94	$6,117.98	$0.00	$0.00	$6,117.98	$1,302.83	$3,776.69	$1,011.16	$6,090.68	$27.30
11	0	-1	$3,695.48	$5,149.44	$0.00	$0.00	$5,149.44	$1,085.70	$3,573.22	$663.14	$5,322.05	-$172.61
11	0	0	$3,675.26	$5,169.66	$0.00	$0.00	$5,169.66	$1,085.70	$3,573.22	$711.09	$5,370.01	-$200.35
20	0	-1	$3,540.11	$5,304.81	$0.00	$0.00	$5,304.81	$1,302.83	$3,573.22	$663.14	$5,539.19	-$234.38
11	0	75	$3,660.17	$5,184.75	$0.00	$0.00	$5,184.75	$1,085.70	$3,573.22	$769.32	$5,428.24	-$243.49
20	0	0	$3,517.77	$5,327.15	$0.00	$0.00	$5,327.15	$1,302.83	$3,573.22	$711.09	$5,587.14	-$259.99
20	0	75	$3,502.94	$5,341.98	$0.00	$0.00	$5,341.98	$1,302.83	$3,573.22	$769.32	$5,645.37	-$303.39
11	0	100	$3,610.93	$5,233.99	$0.00	$0.00	$5,233.99	$1,085.70	$3,573.22	$920.73	$5,579.64	-$345.65
11	0	200	$3,568.13	$5,276.79	$0.00	$0.00	$5,276.79	$1,085.70	$3,573.22	$1,011.16	$5,670.07	-$393.28
20	0	100	$3,448.18	$5,396.74	$0.00	$0.00	$5,396.74	$1,302.83	$3,573.22	$920.73	$5,796.78	-$400.04
20	0	200	$3,420.63	$5,424.29	$0.00	$0.00	$5,424.29	$1,302.83	$3,573.22	$1,011.16	$5,887.21	-$462.92
11	-1	-1	$4,340.59	$4,504.33	$0.00	$0.00	$4,504.33	$1,085.70	$3,398.52	$663.14	$5,147.36	-$643.03
11	-1	0	$4,320.37	$4,524.55	$0.00	$0.00	$4,524.55	$1,085.70	$3,398.52	$711.09	$5,195.31	-$670.76
20	-1	-1	$4,179.64	$4,665.28	$0.00	$0.00	$4,665.28	$1,302.83	$3,398.52	$663.14	$5,364.49	-$699.21
11	-1	75	$4,305.28	$4,539.64	$0.00	$0.00	$4,539.64	$1,085.70	$3,398.52	$769.32	$5,253.54	-$713.90
20	-1	0	$4,157.31	$4,687.61	$0.00	$0.00	$4,687.61	$1,302.83	$3,398.52	$711.09	$5,412.45	-$724.84
20	-1	75	$4,142.48	$4,702.44	$0.00	$0.00	$4,702.44	$1,302.83	$3,398.52	$769.32	$5,470.68	-$768.24
11	-1	100	$4,256.03	$4,588.89	$0.00	$0.00	$4,588.89	$1,085.70	$3,398.52	$920.73	$5,404.95	-$816.06
11	-1	200	$4,213.24	$4,631.68	$0.00	$0.00	$4,631.68	$1,085.70	$3,398.52	$1,011.16	$5,495.38	-$863.70
20	-1	100	$4,087.72	$4,757.20	$0.00	$0.00	$4,757.20	$1,302.83	$3,398.52	$920.73	$5,622.08	-$864.88
20	-1	200	$4,060.17	$4,784.75	$0.00	$0.00	$4,784.75	$1,302.83	$3,398.52	$1,011.16	$5,712.51	-$927.76

* For the Chehalis and Skookumchuck Rivers' five levee improvement level are considered for each with these levels being: "-1" = A levee height one foot below the 100-yr WSE; "0" = A levee height at the 100-yr WSE; "75"= A levee height that has a 75-yr level of flood protection; "100" = A levee height that has a 100-yr level of flood protection; "200" = A levee height of approximately 200-yr level of protection, and "BW" = A backwater levee only option on the Skookumchuck River. As the study is conducted under a risk-based approach, the "100-yr" flood consists of a distribution of floods defined by risk-based parameters as presented in hydraulics and hydrology appendices. For the 100-yr WSE, the mean values of the risk parameters associated with the 1% chance flood were utilized to develop the water surface elevation. To provide protection of a given frequency, and as a flood of a given frequency consists of many differing levels, the height of the levee must contain 95% of that level's distribution of floods.

**Residual damages in this table do not include agriculture damages and rail damages – both these categories are not affected by proposed alternatives. Residual annual damages in these categories are $115,850 for agriculture and $32,200 for rail. Additional project benefits categories of avoided cost of fill for elevating I-5 and reduced traffic delays are presented in other columns in the table.

Table 4-9 indicates net benefits increase as the size of the levee on the Skookumchuck River decreases. The table also indicates that a levee scaled to one-foot below the 100-yr WSE provides greater net NED benefits than no levee construction on the Skookumchuck River other than the backwater levees required to mitigate the influences of the Chehalis River levee on the Skookumchuck River caused by the Chehalis River levees. An analysis was conducted to evaluate Skookumchuck River Levees at two-feet below the 100-yr WSE that demonstrated that NED benefits decreased more than NED costs, resulting in lower net benefits for the –2-foot levee than for the –1-foot levee. This analysis showed that the –1 foot levee was the optimum elevation for Skookumchuck River Levees.

4.12.2 Identification of NED Plan

Based on the above analyses, the structural plan that most reasonably maximizes net NED benefits consistent with protecting the environment, the NED Plan, consists of the following.

- An 11,000 acre-foot modification plan for the Skookumchuck Dam
- Levee construction of 100-year level protection on the Chehalis, and
- Construction of a levee at one-foot below the 100-year WSE on the Skookumchuck River.

Residual damages for the NED Plan are shown in Table 4-10, below.

TABLE 4-10 NED PLAN RESIDUAL DAMAGES

Expected Annual Flood Damage for the NED Plan*

11,000 ac/ft Skookumchuck Dam modification, 100-yr Protection Levee Chehalis River, & 100-yr WSE -1 Skookumchuck Levee

(Damage in $1,000's)

Alternative	Damage Categories											
	Com - Cleanup	Com -Cnt	Com - Str	PA	Res - Cleanup	Res - Cnt	Res - Str	TRA	Pub - Cleanup	Pub - Str	Pub - Cnt	Total
Without Project Damages	301.36	1431.16	1354.95	405.13	866.89	1430.52	2453.00	116.63	28.76	204.65	251.88	8844.92
NED Plan	25.59	198.10	168.46	159.73	312.52	570.90	988.90	46.08	5.06	24.49	33.54	2533.37
Damage Reduction	**275.77**	**1233.06**	**1186.49**	**245.40**	**554.37**	**859.62**	**1464.10**	**70.55**	**23.70**	**180.16**	**218.34**	**6311.55**

**Damages in this table do not include agriculture damages and rail damages – both these categories are not affected by recommended project. Residual annual damages in these categories are $115,850 for agriculture and $32,200 for rail. Additional project benefits categories of NED plan include $2,110,000 in avoided cost of fill for elevating I-5 and $129,100 in reduced traffic delays. Incorporating these values results in the following:*

*Without-project damages including agricultural damages, rail damages, and traffic delays and cost of elevating I-5: **$11,232.06***

*NED Plan residual damages including agricultural damages and rail damages: **$2,681.42***

*NED Plan damage reduction including avoided cost of fill for elevating I-5 and reduced traffic delays: $**8,550.65***

4.13 Evaluation of Project Performance

In addition to the economic basis for selecting an alternative to optimize, engineering performance as described in Section 3.4.5, is also considered. The three performance indices targeted for this analysis were the Expected Annual Exceedance and the Conditional Probability of Non-Exceedance for a series of events and the Long-Term Risks of Exceedance. Table 4-11 reports indices of engineering performance of the various alternative sizes. For reference, the median annual exceedance probability that corresponds to the top-of-levee stage is determined by direct reference to the stage-discharge and discharge-frequency relationships. The reporting of performance is based on the controlling value (lowest performing location) at any of the index locations for each river.

The Expected Annual Exceedance probability, with uncertainty analysis values, equals the annual exceedance probability with uncertainty included. These represent the protection provided, incorporating explicitly the uncertainty in predicting discharge associated with a specified probability and in predicting stage associated with discharge. In each case, the value is the probability with which the stage, with error included, exceeds the specified top-of-levee (or target elevation) in the simulation for economic evaluation. For example, with the Chehalis levee, the simulated water-surface elevation with errors included exceeded the top-of-levee elevation 61,000 times in 5,000,000 iterations. Therefore, the annual exceedance probability is 61/5,000 = 0.0122. The Expected Annual Exceedance for the existing condition is 39.4% on the Chehalis and 17.2% on the Skookumchuck (Reach 4 only). The Expected Annual Exceedance for the Chehalis Levee 2, 11K Dam and 100Skook Lev Plan is 0.2% on the Chehalis and 0.3% on the Skookumchuck (Reach 4 only). The Expected Annual Exceedance for the Chehalis Levee 2, 20K Dam and 100Skook Lev Plan is 0.2% on the Chehalis and 0.2% on the Skookumchuck (Reach 4 only).

The Conditional Probability of Non-Exceedance of the various plans for four benchmark events is also presented in Table 4-11. The values shown are frequencies of not exceeding the levee capacity, given occurrence of the events shown. For example, for the Chehalis Levee 2, the conditional non-exceedance probability for the 0.01 exceedance probability event is 0.957. That means that should a 0.01 exceedance probability event occur, the probability is 0.957 that it would not exceed the capacity of the levee.

A local goal of a preferred alternative would be to provide certification to FEMA for providing protection against a 100-year flood. This requires the Conditional Non-Exceedance Probability to be a minimum of 90% (if freeboard is at least three feet) or 95% if freeboard is less than three feet. The Conditional Non-Exceedance Probability (0.01 Event) for the existing condition is 0% on the Chehalis and 0% on the Skookumchuck (Reach 4 only). The Conditional Non-Exceedance Probability for the Chehalis Levee 2, 11K Dam and 100Skook Lev Plan is 97.7% on the Chehalis and 98.2% on the Skookumchuck (Reach 4 only). The Conditional Non-Exceedance Probability for the Chehalis Levee 2, 20K Dam and 100Skook Lev Plan is 97.8% on the Chehalis and 99.8% on the Skookumchuck (Reach 4 only). Therefore, the Chehalis Levee 2 and 100 Skook Lev Plan can be certified to meeting the requirements of the FEMA and Corps guidance for 100-year protection.

The Long-Term Risks of Exceedance presents the probability that each alternative could be overtopped in a given period of time. For the Levee 2, 11K Dam and 100Skook Lev Plan, for example, there is a 4.7% chance that the Chehalis levee would be exceeded in a 25-year period and an 8.7% chance for the Skookumchuck Levee (Reach 4 only) for the same term. Levee 2, 20K Dam and 100Skook Lev Plan, there is a 4.6% chance that the Chehalis levee would be exceeded in a 25-year period and a 4.7% chance for the Skookumchuck Levee (Reach 4 only) for the same term. For the same period, the existing condition Long-Term risk is 100% on the Chehalis and 99% chance on the Skookumchuck River.

TABLE 4-11 ENGINEERING PERFORMANCE EVALUATION

Alternative	Expected Annual Exceedance %		Equivalent Long-Term Risk						Conditional Probability of Design Containing Indicated Event							
			10 Yrs		25 Yrs		50 Yrs		10%		4%		2%		1%	
	Chehalis	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook	Cheh	Skook
Existing	39.4	17.2	99.3	84.9	100.0	99.1	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11k-100-200sk	0.2	0.2	1.9	1.9	4.7	4.6	9.1	8.9	100.0	99.9	99.9	99.9	99.8	99.9	97.7	99.9
11k-100-100sk	0.2	0.3	1.9	3.6	4.7	8.7	9.1	16.7	100.0	99.9	99.9	99.9	99.8	99.9	97.7	98.2
11k-100-75sk	0.2	0.8	1.9	7.6	4.7	18.0	9.1	32.7	100.0	99.9	99.9	99.9	99.8	99.3	97.7	73.3
11k-100-WSEsk	0.2	1.0	1.9	9.9	4.7	23.0	9.1	40.7	100.0	99.9	99.9	99.9	99.8	96.3	97.7	50.8
11k-100-WSE-1sk	0.2	1.5	1.9	14.1	4.7	31.6	9.1	53.2	100.0	99.9	99.9	99.7	99.8	79.1	97.7	20.6
20k-100-200sk	0.2	0.1	1.9	0.5	4.6	1.3	9.0	2.6	100.0	99.9	99.9	99.9	99.8	99.9	97.8	99.9
20k-100-100sk	0.2	0.2	1.9	1.9	4.6	4.7	9.0	9.1	100.0	99.9	99.9	99.9	99.8	99.9	97.8	99.8
20k-100-75sk	0.2	0.7	1.9	6.4	4.6	15.2	9.0	28.0	100.0	99.9	99.9	99.9	99.8	99.1	97.8	86.3
20k-100-WSEsk	0.2	0.9	1.9	8.6	4.6	20.2	9.0	36.3	100.0	99.9	99.9	99.9	99.8	95.5	97.8	68.3
20k-100-WSE-1sk	0.2	1.4	1.9	13.2	4.6	29.7	9.0	50.6	100.0	99.9	99.9	99.7	99.8	76.7	97.8	34.4

4.14 Phase 3 – Locally Preferred Plan

Following review of the optimization analysis results, the local sponsor (Lewis County) indicated preference for implementation of a locally preferred plan that exceeds the performance, protection, and costs of the NED Plan. The County's preferred plan includes the same three features as identified in the NED Plan, that is, Chehalis River Levees, Skookumchuck Dam modifications, and Skookumchuck River Levees, however in a slightly different configuration as the NED Plan. The Locally Preferred Plan includes:

- The 20,000 acre foot modification plan for the Skookumchuck Dam (as opposed to the 11,000 acre foot modification in the NED Plan)
- Levee construction of 100-yr level protection on the Chehalis (the same as the NED Plan), and
- Construction of a levee providing 100-year protection on the Skookumchuck River (as opposed to the levee at one-foot below the 100-yr WSE, as identified in the NED Plan).

No significant differences in adverse environmental impacts were identified in the EIS process between the NED Plan and the Locally Preferred Plan. For this reason, the same mitigation features and cost were applied to both plans.

4.15 Environmental Impacts of NED and Locally Preferred Plans

The identified flood control alternatives are expected to not likely to adversely affect Federally listed fish and wildlife species. Impacts were identified however for riparian and wetland communities. No significant differences in adverse environmental impacts were identified in the EIS process between the NED Plan and the Locally Preferred Plan (LP Plan). For this reason, the same impact estimate was derived for each plan.

The NED and LP Plans include the setback levees to protect developed areas, plus includes Skookumchuck Dam modifications. The current proposed levee alignment runs from Ford Prairie, south and east to I-5, south along the west side of I-5, around the Chehalis-Centralia Airport, and ending at the southern end of the airport adjacent to I-5. Additional levees occur on both banks of the Skookumchuck between the Coffee Creek and Chehalis confluences, on the north side of Salzer Creek from Salzer Valley Road to the connection with the I-5 levee, and along Dillenbaugh Creek from Chehalis Junction to Fern Hill Cemetery. The levees have been optimized to minimize the footprint of the levee system.

The NED and LP Plans would result in the direct loss of wetlands and riparian areas within the footprint of the levees. Table 4-12 provides a summary of the total of wetland and riparian impacts from the levee footprint by specific areas. The only wetland type within the project footprint is farmed wetlands and/or emergent wetlands. As such, the wetland impact acreage is based on extent of mapped hydric soils.

TABLE 4-12 PROJECT FEATURES, LINEAR FEET, TOTAL ACREAGE OF PROJECT FOOTPRINT, AND TOTAL IMPACT AREAS FOR RIPARIAN AREAS AND WETLANDS

Reach #	Project	Feature	Linear Feet	Total Acreage	Riparian Areas[7] (Acres)	Wetlands[8] (Acres)
	Levee	Wall				
1	X		14,676	11.500	0.00	0.00
2	X		658	0.500	0.00	0.00
3a		X	700	0.010	0.00	0.00
3b	X existing		3,000	0.000	0.00	0.00
3c		X	700	0.010	0.00	0.00
3d	X		2,905	5.200	0.00	5.00
4	X		12,599	11.700	0.00	11.70
5	X		4,767	4.500	0.00	4.50
6a	X		1,445	1.400	0.00	1.30
6b		X	1,034	0.010	0.00	.01
7a	X		12,792	9.000	0.00	7.00
7b		X	1,305	0.800	0.00	0.00
8a		X	250	0.003	0.00	0.00
8b		X	150	0.002	0.00	0.00
8c	X		1,511	1.600	0.00	1.40
9a	X		185	0.200	0.00	0.00
9b	X		60	0.003	0.00	0.00
9c	X		2,581	3.100	0.00	3.10
10		X	1,750	0.020	0.00	0.00
11	X		2,331	1.600	0.00	0.00
12	X		3,834	3.400	0.00	0.00
13		X	3,050	0.040	0.00	0.00
14	X		2,082	2.200	0.60	0.00

[7] Forested riparian areas were the only type within the impact area footprint
[8] Farmed and/or emergent wetlands were the only type within the impact area footprint

15	X		3,869	2.700	0.00	0.00
16	X		3,419	2.700	0.20	0.00
Totals			**81,653**	**62.198**	**0.8**	**34.01**

Total wetland loss is estimated to be 34 acres of wetlands over approximately 15 miles of levees and floodwalls. Approximately 14 miles of the preferred alternative consists of levees and 1 mile of floodwall. Mitigation will be required to offset this loss of wetlands/riparian areas.

There will be loss of vegetation, with the NED or LP Plan, though these impacts are being minimized with design refinement. The impacts to vegetation were not found to be significant enough to require mitigation.

Throughout the development of the NED and LP Plans, minimization of impacts to sensitive areas was followed as a basis of design. Care was taken to stay close to developed areas, keeping the alignment setback as far as possible from the Chehalis River and its tributary streams, wetlands, and riparian areas. The design also incorporated areas of existing levees or tied into an existing levee system wherever practicable. Lastly, floodwalls were incorporated into the design where levees would have encroached upon the river.

The Corps will continue to evaluate measures during the design process methods to avoid direct impacts to vegetation, wetlands, and riparian areas. These measures may include:

- Additional adjustments to the levee alignment, where possible, to avoid direct impacts.
- Evaluation of the changes to the flood regimes of the Skookumchuck River.

Measures that would avoid and or reduce potential indirect impacts include:

- Strict controls on construction stormwater to avoid direct discharges to wetlands and other aquatic habitats.
- Place of construction areas away from wetland and riparian habitats.
- Placement of construction access roads outside of wetland and riparian areas.

Chapter 4 in the EIS titled “Environmental Effects,” provides specific effects on various reaches of the Chehalis and Skookumchuck Rivers.

4.16 Formulation of Mitigation Plan

In the formulation of the proposed mitigation plan, a variety of different environmental mitigation sites and features were evaluated to identify a cost effective mitigation plan. Formulation of the mitigation plan was based upon findings of environmental studies conducted as part of the General Reevaluation study that:

- Identified basin-wide limiting factors to fish and wildlife production
- Assessed, quantified, and documented existing habitat conditions by subbasins in the study area
- Identified geomorphic constraints and opportunities for restoring site-specific degraded habitats
- Identified watershed-scale opportunities to address limiting factors
- Formulated a range of potential environmental projects
- Developed an evaluation framework for quantifying environmental conditions
- Quantified environmental benefits of environmental projects
- Quantified environmental impacts of flood control alternatives
- Identified cost effective mitigation strategies

After reviewing the above listed parameters, mitigation features were identified and evaluated throughout the study area. These features were formulated to provide mitigation within the project area to address project impacts to significant sensitive resources.

4.16.1 Potential Mitigation Features

A range of potential environmental projects was identified that addressed findings of the limiting factors analysis and would provide key habitats throughout the study area. The potential mitigation components evaluated are presented in Table 4-13.

TABLE 4-13 POTENTIAL MITIGATION AREAS/COMPONENTS

Alternative
Schueber Ditch/SR6 Area
Chehalis River Mainstem Oxbows
Chehalis River Mainstem, RM 66-80
Skookumchuck, Chehalis Confluence
Skookumchuck, RM 12
SF Chehalis, RM 0-5
SF Chehalis, Chehalis Confluence
Newaukum, Chehalis Confluence
Newaukum, Stan Hedwall Park
Newaukum, RM 0-10
NF Newaukum, SF Confluence
MF Newaukum, Tauscher Road
NF Newaukum, Tauscher Road
Salzer Creek, Chehalis Confluence
Salzer Creek, Frozen Food Site
Salzer Creek, RM 3.1
Salzer Creek, RM 4.5

An environmental evaluation methodology was designed for the study to provide a numerical estimate of the benefits provided by alternative mitigation plans. It also assisted in gathering information needed to assess mitigation needs and options during the formulation process. The framework was intended to differentiate benefits across alternatives and to provide information required for cost effectiveness and incremental cost analysis. An evaluation panel was utilized, composed of representatives from the Tribes, Corps, US Fish & Wildlife Service, US EPA, Washington Department of Fish and Wildlife, Washington Department of Ecology, Washington Department of Transportation, Gray's Harbor County, Thurston County, and Pacific International Engineering, Inc., representing the local sponsor Lewis County and facilitation by Tetra Tech. Inc. The evaluation panel met to determine scores for both the existing and with-project conditions. Generally, the score is a reflection of consensus amongst the panel members.

Cost and output estimates were developed for the components from Table 4-13. These estimates were used in a preliminary cost effectiveness and incremental cost analysis to evaluate the cost effectiveness of the various mitigation options. The output estimates were derived by the evaluation framework process described in the above paragraph, and are measured in habitat units. Cost estimates were developed that included design costs, construction costs, real estate costs, and operation and maintenance costs. This analysis is presented as an appendix to the EIS.

As mitigation planning progressed, the Schueber Ditch/SR6 area was identified by the resource agencies as a priority zone for development of mitigation features. Focusing on mitigation principally within the Schueber ditch area was found to consolidate multiple mitigation objectives and to achieve added benefits through increased floodplain connectivity and improved interaction between wetland, fish and wildlife ecology. It was the only area with the potential to provide all required mitigation in a contiguous area.

Multiple combinations of environmental features in this area were developed and evaluated as a result. Many of these components were found to be relatively cost effective mitigation components as compared to other components in other areas and would be incrementally justified when compared with these other mitigation options. In addition, the EIS determined that the components in the Schueber Ditch/SR6 area offered adequate environmental benefits to offset adverse environmental impacts of the NED and LPP flood damage reduction features. Based upon these findings, mitigation plan formulation focused on the Schubert Ditch/SR6 area from this point forward. Table 4-14 lists the mitigation alternatives evaluated in this area with their annual cost and output estimates.

TABLE 4-14 POTENTIAL MITIGATION COMPONENTS WITH COST AND OUTPUT ESTIMATES

Mitigation Alternative	Cost	Output
No Action	0	0
Oxbow Reconnection + Schueber Ditch Restoration	$672,200	1,413.00
Oxbow Reconnection+ South Wetand	$1,309,800	2,837.72
Oxbow Reconnection+ Schueber Ditch Restoration + North Wetland	$1,270,700	2,862.86
Oxbow Reconnection+ Schueber Ditch Restoration+ South Wetland	$1,625,100	2,878.28
Oxbow Reconnection+ Schueber Ditch Restoration+ South Wetland + North Wetland	$2,104,300	2,905.96
Oxbow Reconnection+ Schueber Ditch Restoration+ South Wetland + North Wetland + Middle Wetland	$3,812,600	2,989.15

4.16.2 Cost Effectiveness and Incremental Cost Analysis

Cost effectiveness and incremental cost analyses were conducted to evaluate the relative cost efficiency of the various alternative mitigation plans listed in Table 4-14. Mitigation plans were screened from further analysis as “non-cost effective” if they provided the same or less output as other combinations at a higher cost. The remaining set of “cost-effective” combinations were evaluated through an incremental cost analysis to identify the variations in cost and output provided by the cost effective plans.

The analysis identifies those plans, referred to in this report as "best-buys", that provide the greatest increases in environmental output for the least increase in cost. The first best buy combination identified produces output at the lowest incremental cost per habitat unit of all plans considered. The second best buy is the plan that provides additional output at the next lowest cost per habitat unit. The results of the incremental cost analysis are presented in Table 4-15 and graphically in Figure 4-1.

TABLE 4-15 INCREMENTAL COST ANALYSIS

Mitigation Alternative	Annual Cost	Output	Incremental Cost	Incremental Output	Inc Cost per Unit
1 No Action	0	0			0
2 Oxbow + Schueber Ditch + N Wetland	$1,270,700	2,862.86	$1,270,700	2,862.86	$444
3 Oxbow + Schueber Ditch + S Wetland + N Wetland	$2,104,300	2,905.96	$833,600	43.10	$19,341
4 Oxbow + Schueber Ditch + S Wetland + N Wetland + M Wetland	$3,812,600	2,989.15	$1,708,300	83.19	$20,535

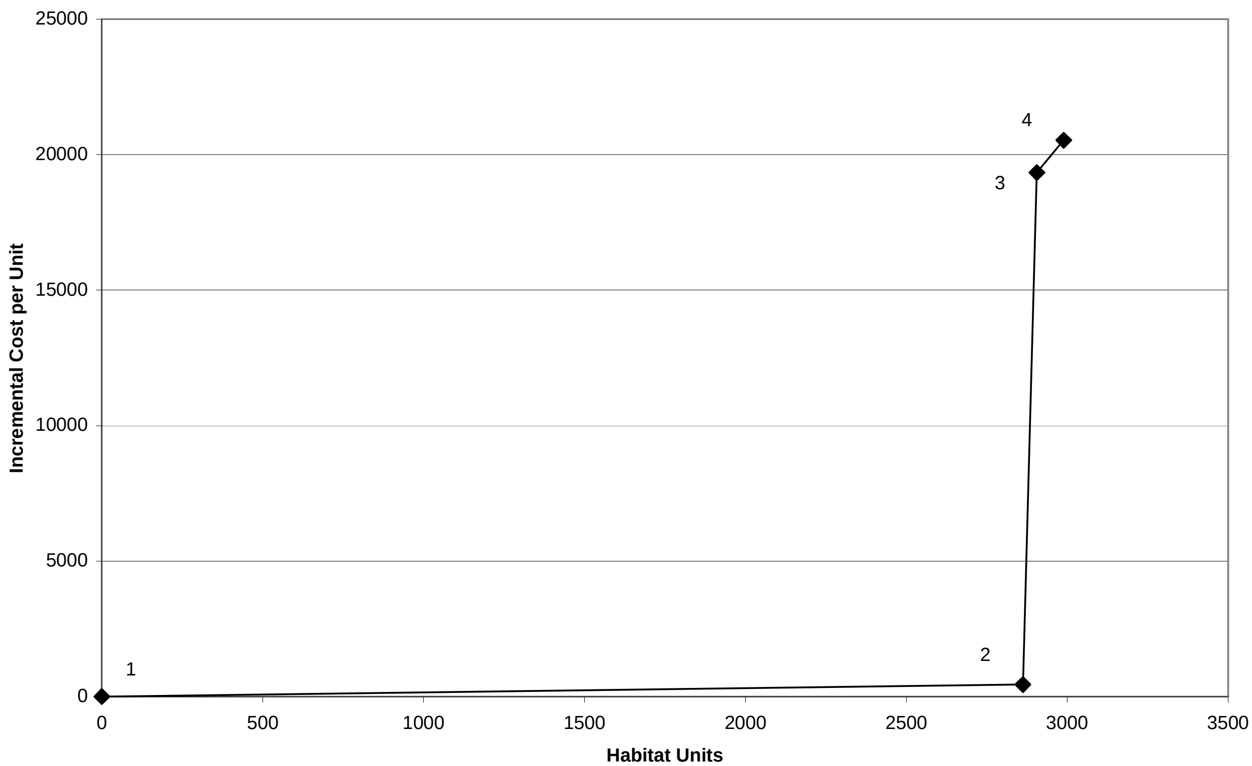

Figure 4-1 Incremental Cost Analysis of Mitigation Plans

Examining Figure 4-1, incremental costs remain relatively low through Plan #2. Increasing output beyond that is characterized as getting relatively small increases in output for high increases in cost. It was determined that additional output beyond that provided by Plan #2 was not worth its cost and that Plan #2 would be the proposed mitigation plan.

Features of Mitigation Plan #2 include:

- Reconnection of oxbow (north of SR6) to the Chehalis River in over bank events
- Conveyance of flows from reconnected oxbow under SR6 to Scheuber Ditch Restoration Area
- Development of wetland complex to the north of the Scheuber Ditch Restoration Area

5. SELECTED PLAN

5.1 Description of Selected Plan

The plan selected for recommendation is the Locally Preferred Plan. This plan was selected because the local sponsor desired the added protection from the 20,000-acre foot dam and FEMA certification for the 100-year flood for additional areas in Centralia.

The Locally Preferred Plan includes:

- The 20,000 acre foot modification plan for the Skookumchuck Dam
- Levee construction of 100-yr level protection on the Chehalis
- Construction of a levee providing 100-year protection on the Skookumchuck River
- Elevation of structures that would incur increased inundation as a result of the project to mitigate for induced damages.

5.2 Cost of Selected Plan

A detailed cost estimate was developed for the selected plan. The life-cycle project cost estimate is $111,800,000 and includes design and construction costs, mitigation costs[9], operation and maintenance costs, real estate acquisition costs, contingency, and interest during construction.[10] This is a difference of $8,100,000 over the NED Plan, which has a life cycle project cost estimate of $103,700,000. Both estimates include the addition of costs for elevating structures that would incur increased inundation with the project to mitigate for induced damages as described in Section 5.5.1. Complete estimates are presented in Appendix D, Cost Engineering.

The implementation cost estimate for the NED plan and the selected plan were developed using the Corps Micro Computer Aided Cost Estimating Software (MCACES). Table 5-1 presents the

[9] The mitigation costs are estimated on the impacts of a 35% design of the project, further minimization of the impacts will be conducted in PED, thus reducing the costs. This is consistent with the EIS process. During PED mitigation costs tied specifically to the minimized impacts will be identified and the appropriate portions of the plan will be utilized.

[10]These NED costs differ from those presented in Chapter 4, Plan Formulation to reflect the most recent refinements in the cost estimate at the time of report publication. The differences were found to not have any significant effect on plan formulation and selection.

NED cost estimate. Table 5-2 presents the Selected Plan cost estimate. The differences in cost between the two plans are shown in Table 5-3. No significant differences in adverse environmental impacts between the NED Plan and the Locally Preferred Plan were identified in the EIS process. For this reason, the same mitigation features and cost were applied to both plans.

TABLE 5-1 MCACES COST ESTIMATE FOR NED PLAN

CURRENT ESTIMATE PREPARED:		Jun-02				AUTHORIZ./BUDGET YEAR: 2002				FULLY FUNDED ESTIMATE				
EFFECTIVE PRICING LEVEL:		Jun-02				EFFECT. PRICING LEVEL: Mar-02								
ACCOUNT NUMBER	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
04	Dams													
	1. Lower Dam Alternative (11,000 acre fe	4,827.2	1,690	35%	6,517	0.0%	4,827	1,690	6,517	Jul-05	8.2%	5,222	1,828	7,050
06	FISH AND WILDLIFE													
	1. Mitigation	11,648.4	2,912	25%	14,561	0.0%	11,648	2,912	14,561	Jul-05	8.2%	12,601	3,150	15,751
11	LEVEES AND FLOODWALLS													
	1. Levee Alternative	29,421.5	7,355	25%	36,777	0.0%	29,421	7,355	36,777	Jul-05	8.1%	31,814	7,953	39,767
	2. Skookumchuck Region (-1' of 100 year WSE)	4,444.2	1,111	25%	5,555	0.0%	4,444	1,111	5,555	Jul-05	8.1%	4,806	1,201	6,007
	TOTAL CONSTRUCTION COSTS	**50,341**	**13,068**	**26%**	**63,409**	**0.0%**	**50,341**	**13,068**	**63,409**		**8.1%**	**54,443**	**14,133**	**68,575**
01	LANDS AND DAMAGES													
	1. Real Estate	14,270.0	0	0%	14,270	0.0%	14,270	0	14,270	Jul-05	8.1%	15,430	0	15,430
30	PLANNING, ENGINEERING AND DESIGN	5,034.1	1,259	25%	6,293	0.0%	5,034	1,259	6,293	Apr-04	7.4%	5,405	1,351	6,756
31	CONSTRUCTION MANAGEMENT	5,034.1	1,259	25%	6,293	0.0%	5,034	1,259	6,293	Jul-05	8.1%	5,443	1,361	6,804
	TOTAL PROJECT COSTS	**74,680**	**15,585**	**21%**	**90,265**	**0.0%**	**74,680**	**15,585**	**90,265**		**8.1%**	**80,721**	**16,845**	**97,566**

TABLE 5-2 MCACES COST ESTIMATE FOR SELECTED PLAN (LOCALLY PREFERRED PLAN)

CURRENT ESTIMATE PREPARED:		Jun-02				AUTHORIZ./BUDGET YEAR: 2002				FULLY FUNDED ESTIMATE				
EFFECTIVE PRICING LEVEL:		Jun-02				EFFECT. PRICING LEVEL: Mar-02								
ACCOUNT NUMBER	FEATURE DESCRIPTION	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	OMB (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	FEATURE MID PT	OMB (%)	COST ($K)	CNTG ($K)	FULL ($K)
04	Dams													
	1. High Dam Alternative (20,000 acre fee	6,589.6	2,306	35%	8,896	0.0%	6,590	2,306	8,896	Jul-05	8.2%	7,129	2,495	9,623
06	FISH AND WILDLIFE													
	1. Mitigation	11,648.4	2,912	25%	14,561	0.0%	11,648	2,912	14,561	Jul-05	8.2%	12,601	3,150	15,751
11	LEVEES AND FLOODWALLS													
	1. Levee Alternative	29,421.5	7,355	25%	36,777	0.0%	29,421	7,355	36,777	Jul-05	8.1%	31,814	7,953	39,767
	2. Skookumchuck Region (100 - year protection)	7,126.1	1,782	25%	8,908	0.0%	7,126	1,782	8,908	Jul-05	8.1%	7,706	1,926	9,632
	TOTAL CONSTRUCTION COSTS	**54,786**	**14,355**	**26%**	**69,141**	**0.0%**	**54,786**	**14,355**	**69,141**		**8.1%**	**59,249**	**15,525**	**74,774**
01	LANDS AND DAMAGES													
	1. Real Estate	14,270.0	0	0%	14,270	0.0%	14,270	0	14,270	Jul-05	8.1%	15,430	0	15,430
30	PLANNING, ENGINEERING AND DESIGN	5,478.6	1,370	25%	6,848	0.0%	5,479	1,370	6,848	Apr-04	7.4%	5,882	1,470	7,352
31	CONSTRUCTION MANAGEMENT	5,478.6	1,370	25%	6,848	0.0%	5,479	1,370	6,848	Jul-05	8.1%	5,924	1,481	7,405
	TOTAL PROJECT COSTS	**80,013**	**17,095**	**21%**	**97,107**	**0.0%**	**80,013**	**17,095**	**97,107**		**8.1%**	**86,485**	**18,477**	**104,962**

TABLE 5-3 COST COMPARISON OF NED AND LOCALLY PREFERRED PLAN

	Construction Cost*	Real Estate	Mitigation Cost	PED/Const. Mgmt.	Total First Costs	Interest During Construction	O&M Cost	Total Life Cycle Project Cost	Average Annual Equivalent Cost
Locally Preferred Plan	$54,581	$14,270	$14,561	$13,695	$97,107	$4,694	$9,995	$111,800	$7,220
NED Plan	$48,849	$14,270	$14,561	$12,585	$90,265	$4,418	$8,969	$103,700	$6,700
Cost Difference	$5,732	$0	$0	$1,110	$6,842	$276	$1,026	$8,100	$500

All costs are in present value (March 2002 price level; dollars in $1,000)(Numbers may not add due to rounding)
** Construction cost does not include mitigation cost which is broken out seperately*

5.3 Benefits of Selected Plan

The selected plan provides estimated annual benefits of $8,765,000, including $6.5 million in flood related damages to structures and their contents, $2.1 million in annual avoided costs associated with the need to elevate Interstate Highway 5 without the project, and an annual reduction of $129,000 in traffic delays related to flooding. Residual annual damages in the study area amount to $2.5 million (including flood damages associated with structures and contents as well as residual agricultural damages and rail delay damages; neither of these latter two damage categories are affected by the NED or the selected Locally Preferred Plans).

Annual economic costs of the locally preferred plan are estimated at $7,220,000, resulting in annual net benefits of $1,545,000 and a positive benefit to cost ratio of 1.21 to 1. The recommended project is supported by the local sponsor, Lewis County, Washington. The NED Plan costs $6,700,000, providing net benefits of $2,065,000 at a benefit to cost ratio of 1.31 to 1.

5.4 Structural Flood Control Features of Selected Plan

The selected plan includes a combination of structural flood damage reduction features. These include:

- Chehalis River Levee System
    - Chehalis River Mainstem Levees
    - Salzer Creek Levees
    - Dillenbaugh Creek Levees

- Skookumchuck River Levee System

- Modified Outlet Works and New Gates on the Spillway at Skookumchuck Dam for the addition of 20,000 acre-feet of flood control storage.

Design of the levee system took advantage of opportunities to maximize levee setbacks, allowing floodplain and channel connectivity for environmental purposes. The setback levee alignment will protect existing residential and commercial structures, highway and other transportation infrastructure from flooding while not encouraging new floodplain development. Proposed protection would extend along the Chehalis River from approximately River Mile 75 to River Mile 64, as well as along most of the lower two miles of both Dillenbaugh Creek and Salzer Creek. In addition, levee protection will be provided on the Skookumchuck River for backwater effects of the Chehalis River and flooding from the Skookumchuck River. The affected reach (Skookumchuck River Reach 4) is approximately 2 miles upstream on the Skookumchuck to the confluence with Coffee Creek.

The levee system is intended to provide 100-year protection from the Chehalis River flooding. This protection also extends to the tributaries of the Chehalis River. The Chehalis backwater flooding is prevented from going upstream on the following tributaries: Dillenbaugh Creek, Salzer Creek, China Creek, Coal Creek and the Skookumchuck River.

A proposed modification to Skookumchuck Dam will provide flood control storage of approximately 20,000 acre-feet between pool elevation 455 and 492 feet. The current elevation of the existing spillway crest is 477 feet, with an uncontrolled spillway. With this flood storage pool elevation the reservoir would provide approximately 20,000 acre-feet of flood control storage.

The proposed design includes modification to the spillway chute and installation of a short tunnel outlet with slide gates; this is Alternative #2B2. Modification of the dam will reduce the flood stages along the lower Skookumchuck River up to one foot during a 100-year flood. There is more significant reduction in a 10 to 50- year flood events, up to 2.4 feet reduction in stage. This will provide significant flood damage reduction to the communities along the river. In addition the dam will provide incidental hydraulic mitigation downstream in the Chehalis River. The modification will also allow for not only flood control but also for control on releasing summer low flows.

5.5 Non-Structural Flood Control Features of Selected Plan

The Corps considered nonstructural components during the evaluation process. As part of the recommended plan, several structures will be elevated in the floodplain. In addition, other nonstructural features were also considered. Many of these features are already being implemented at the County and City level. They include ordinances on construction in the floodways, emergency warning systems, and other nonstructural solutions such as raising of homes and businesses and property buyouts. Land use management options are also in the process of being revised by the project sponsor to have more restrictive requirements.

Several nonstructural components that will be a locally provided element of the recommended plan, include new FEMA floodplain mapping, flood warning system, restriction of development, restriction of fill in the floodplain, and stormwater management. The following describes these features, how they are currently implemented and what additional measures are under consideration for the new floodplain management plan. These features are the responsibility of the local communities and are not required for the recommended structural features of the plan to function. Further effort on nonstructural options will be evaluated during the development of a new floodplain management plan for the project area to be compliant with Executive Order 11988, concurrent with the design process for the recommended project.

The following are nonstructural components that are being considered for implementation in the project area:

Non Structural Feature	**Lead Implementing Parties**
Elevation of Structures	Corps and local sponsor (component of cost-shared plan)
Define New 100-yr FEMA floodplain	Local communities
Flood Warning System	Local communities
Restriction of Development	Local communities
Restriction of Fill in Floodplain	Local communities
Stormwater Management	Local communities

5.5.1 Elevation of Structures

Both the NED and the Locally Preferred Plan structural alternative will result in slightly increased flood elevations over existing conditions (average of 4 inches for the 100-year event) for eight residential structures in the study area 100-year flood plain. To address this issue, a non-structural analysis was conducted of raising affected structures so that first floor elevations would be one foot above the with-project 100-year water surface elevation (WSE). The estimated implementation cost is based on cost data obtained for previous Corps studies, which indicates an average of $25,000 per residence. Most of the costs of raising a structure are incurred in separating the structure from its foundations and installing a raised foundation. The height of this raised foundation is not generally a significant factor in the total cost and was not used in this estimate. However, the average number of feet these structures are below the 100-year WSE is included for information.

There are two study area sub-areas in which the affected structures are located. The 8 structures would be raised an average of 1.85 feet for a total cost of $200,000 (or an average annual cost of $12,900). The flood damage reduction benefits of raising these structures were based on data taken from the HEC-FDA model results. This data indicated average annual flood damage reductions of $1,730 per structure, or $13,840 for all 8 structures. Comparing average annual benefits of $13,840 to average annual costs of $12,910 results in a benefit-to-cost ratio of 1.1 to 1.0 for this non-structural project component.

The two sub-areas with the number of affected residences, their average elevations below the 100-year without and with-project WSE, and the first cost and average annual cost to elevate to one foot above the 100-year with-project WSE are presented below:

TABLE 5-4 COSTS OF ELEVATING STRUCTURES WITH INDUCED FLOODING

Sub-Area	Number of Affected Residences	Ave Elevation Below 100yr WSE Without Project	Ave Elevation Below 100yr WSE With Project	Average Change in 100yr WSE due to project	First Cost Estimate	Average Annual Costs @ 6.125% over 50 Years
BELOW AIRPORT	6	0.66	1.2	0.51	$ 150,000	$ 9,682
NORTH OF SR6	2	0.29	0.5	0.18	$ 50,000	$ 3,228
Totals/Averages	8	0.475	0.85	0.345	$ 200,000	$ 12,910

5.5.2 Define a New 100-Year FEMA Floodplain

A new 100-year FEMA floodplain map will be generated after the recommended plan has been approved and FEMA has accepted that the project will be completed. This map will be adopted by the communities.

5.5.3 Flood Warning System

Currently the cities and the county utilize the Emergency Broadcast System (EBS) and other forms of public venues such as radio and television to transmit emergency and warning transmissions for the area. Also, 3 local emergency /information phone numbers have been established to answer the public's questions or receive important flood information from residents. There are also neighborhood notification networks. Lewis County Emergency Management division is responsible for carrying out the emergency response program. The City of Chehalis has warning sirens to notify the community, as well as a telephone network through the Chamber of Commerce. They also utilize a website to show where flooding is occurring. The community is also working with the National Weather Service to post bulletins of flood hazards. The flood warning system will be further addressed in the flood management plan.

Additional initiatives that are being considered by the County include:

1) Installing additional river gauging stations to help in flood warning and emergency response activities. Potential additional gauges may include the following:

a. Updating Newaukum gauge near Chehalis with telephone-linked capabilities.
b. Add telephone linked gauge at South Fork Chehalis
c. Install gages on other major tributaries within the Centralia/Chehalis area.

2) The Cities of Chehalis and Centralia and the County Engineer will coordinate the flood forecasting efforts.

3) Formalize and update road closure database creating a predictive tool by coordinating related flood stages to road closures.

4) Increase distribution of flood information materials to being not only available at the Emergency Management Office but also at libraries throughout the county.

5) Update Federal Insurance Rate Maps based on historical flood records to provide more accurate flood hazard information.

6) Provide a public disclosure ordinance of property’s flood plain status at the time of purchase.

7) Document flood warning and emergency response activities for submittal to Community Rating System. These will count as credits to reduce flood insurance premiums.

5.5.4 Restriction of Development

The Corps will determine in the design phase the new floodway and flow paths within project area after the implementation of the structural features. The local community will utilize this to ensure that their ordinances are being followed. This would include utilizing the newly developed 100- year floodplain and hydraulic modeling. The local jurisdictions can either adopt their own Flood Hazard and SEPA ordinances and their own Shoreline Master Programs, as directed under the state Shoreline Management Act or utilize the State's guidelines. In addition to defining the 0.2 ft. floodway, development is also discouraged within additional critical portions of the floodplain, specifically in areas considered to be significant flow paths. Flow paths are naturally occurring swales, which are normally dry, but which historically conveyed significant amounts of flowing water during flood stage. The following is a brief description of the current ordinances for floodway construction for Lewis County, City of Chehalis and the City of Centralia. These ordinances generally support having an approved filling/floodplain development plan, and provide a hydraulic analysis to show a 0.2 ft rise or less in the floodwater surface elevation.

- Lewis County- Development within the FEMA floodway is highly discouraged. New residential structures are entirely prohibited. Commercial development is allowed, but only if accompanied by an engineer's certification that the proposed development would not raise flood levels at all during the 100-year flood. Variances are possible for development within the floodway but Lewis County.
- City of Centralia - Development is not allowed in the FEMA floodway. Request for variances are few and are seldom granted. The applicants that lie in both the Flood Plain Ordinance and the Shoreline Master Program areas are required to apply for, and obtain, both permits. In addition, any development within the FEMA flood fringe must be elevated to at least 1 foot above the elevation of the 100- year flood (these elevations are based on the FIRM).
- City of Chehalis- Development within the FEMA floodway is highly discouraged. New residential structures are entirely prohibited in special flood hazard areas. Commercial development is allowed, but only if accompanied by an engineer's certification that the proposed development would not raise flood levels at all during the 100-year flood. In addition, all new development and substantial improvements will comply with all applicable flood hazard reduction provisions of the city, stat and federal regulations.

5.5.5 Restriction of Fill in the Floodplain

This initiative is to ensure that there are restrictions to new filling of the floodplain by requiring that fill be mitigated by removal of equal volume of fill at the site or elsewhere in the floodplain or floodway. Cut and fill balances should be retained within the project site whenever possible. In the current Comprehensive Flood Hazard Management Plan for Lewis county details adding the requirement for compensatory storage to the Flood Damage Prevention Ordinance is a method for reducing the effects of filling in the flood fringe. Whenever fill material is added to the flood fringe, the area that the fill occupies is removed from the potential flood storage area. Under compensatory storage requirements, any individual placing fill in the flood fringe must excavate an area of equivalent volume to eliminate the effects of the fill material on the flood storage.

- City of Centralia: Filling in the Flood Fringe landward of the floodway is allowed. All construction must be consistent with the model National Flood Insurance Regulations.
- Lewis County: Their standard is that fill materials must be obtained from the site to the extent practicable. If the fill cannot be so obtained from the same site, it must be obtained as practical from the flood hazard area. In addition, the fill must have a beneficial use and deemed necessary.
- City of Chehalis: As a part of the Shoreline Management plan there is a restriction of a one to one fill and cut within the floodplain area.

5.5.6 Storm Water Management

This initiative relates to increasing the detention from a 25-year design storm to meet the Washington State Department of Ecology storm water management criteria. The communities are evaluating these new criteria and determining whether they can meet the new Ecology regulation. A better management of stormwater will assist in reduction of flooding in the project area. The Corps will continue to evaluate the timing of stormwater versus the watershed runoff, to determine an optimum management of stormwater release during a flood event. Stormwater is only a small portion of the basin hydrology.

5.5.7 Non-Structural Summary

The elevation of homes is a cost-shared feature of the recommended plan. The local sponsor to the maximum extent practicable will implement the other nonstructural features at 100% non-Federal cost. These actions will be represented in the revised floodplain management plan for the project as required by Executive Order 11988. This plan will be completed prior to the signing of the cooperative agreement. The Corps will provide technical support to assist in development of sound actions within the project area to assure the integrity of any project structural components.

5.6 Skookumchuck Dam Operational Modification Description

The hydraulic design of the flood control outlet works, and the flood control regulation rule curves for Skookumchuck Dam will need to be refined and finalized in the next phase of studies. Approval and implementation of the re-operation plan is the responsibility of the Corps Water Management office. In addition to hydraulic and engineering considerations, downstream environmental requirements related to reservoir operation and flood control regulation will continue to be a part of the operation plan.

The dam modifications currently being proposed could provide, approximately, an additional 9,000 acre-feet of storage between pool El. 477 and El. 492, bringing the total storage at Skookumchuck Dam to 20,000 acre-feet. This additional storage could potentially be available to augment summer low flows downstream if it were determined that this would be environmentally beneficial. This would, however, require a change in the current reservoir conservation pool level and is not being proposed at this time for the flood reduction project. If this action were to be pursued in the future, any potential environmental impacts and dam safety issues associated with a higher conservation pool would need to be addressed.

5.7 Environmental Mitigation Features and Benefits of Selected Plan

Environmental mitigation features were identified in the vicinity of State Route 6 and the Scheuber Drainage Ditch. Mitigation features include:

- Reconnection of oxbow (north of SR6) to the Chehalis River in over bank events
- Conveyance of flows from reconnected oxbow under SR6 to Scheuber Ditch Restoration Area
- Development of wetland complex to the north of the Scheuber Ditch Restoration Area

The cost estimate for these features is $20,870,000. As documented in the EIS, these features were determined adequate to offset adverse environmental impacts of the project's flood control features, including the 34 acres of impacted wetlands and .8 impacted acres of riparian habitats. These features are described in detail in the EIS.

5.8 Real Estate Requirements of Selected Plan

The proposed flood damage reduction project will require approximately 107 acres of land to implement the recommended levee and floodwall elements, 387 acres to implement the project mitigation elements and 871 acres at the Skookumchuck Dam site, which includes the current water impoundment area behind the dam, for a total project footprint of 1365 acres. The project sites are proposed on lands that are currently in both public and private ownership; approximately 11 public owners and 185 private owners. Commercial borrow and disposal sites will be utilized. Standard estates to be acquired include fee simple, flood control levee easement, temporary work area easement, and a restrictive easement. In addition, non-standard estates developed for this project are being submitted with the project Real Estate Plan (REP) for higher authority review and approval with this report. The proposed non-standard estates include an estate to be used where an existing road is utilized as a flood protection levee, and an estate that will provide perpetual access to floodwalls and levees where access from a public right-of-way is not available.

Project implementation is planned to occur in three separate construction phases. After the Project Cooperation Agreement (PCA) is executed, the Non-Federal Sponsor (NFS) will have approximately 12 months to complete Phase 1 real estate acquisitions, 24 months to complete Phase 2 acquisitions, and 36 months to complete acquisitions for Phase 3. Table 5-5 below provides a summary of the proposed phased acquisition schedule. The NFS will have 180 days after certifying lands available for each construction phase to provide the District Real Estate Division with all supporting lands, easements and rights-of-way (LER) crediting documentation.

Refer to the REP, Appendix F of the GRR, for additional real estate information. See Exhibit A of the REP for real estate maps. See Exhibit B of the REP for an assessment of NFS acquisition capability. See Exhibit C of the REP for the Certification of Lands and Attorney's Certificate. Table 5-5 below provides a summary of the real estate baseline cost estimate (BCERE) for land values, NFS administrative costs and Federal review and assistance costs for implementing the proposed project. A 20% contingency is utilized to cover possible land value variations over time. A 35% contingency is utilized for NFS administrative costs and Federal review and assistance due to various issues that must be addressed in the next project phase when the proposed project design is refined.

TABLE 5-5 SUMMARY BASELINE COST ESTIMATE FOR REAL ESTATE (BCERE)

Site Names	Acres	Land Values	NFS Admin Costs	NFS LERRD	FED S&A
Chehalis Levees	91	$4,752,000	$713,000	$5,465,000	$289,000
Dillenbaugh Levees	1	$39,000	$37,000	$76,000	$33,000
Skookumchuck Levees	15	$2,369,000	$446,000	$2,815,000	$241,000
Mitigation Sites	387	$3,264,000	$376,000	$3,640,000	$149,000
Skookumchuck Dam	871	$1,460,000	$64,000	$1,524,000	$44,000
TOTALS:	1365	$11,884,000	$1,636,000	$13,520,000	$756,000

Land Values include a 20% contingency, and NFS Admin. Costs and Federal Review and Assistance Costs both include a 35% contingency.

Project construction is expected to occur in 3 consecutive phases pursuant to the award of 8 separate construction contracts (See, General Reevaluation Report, Table 6-1, Construction Sequencing, page 157).

TABLE 5-6 LER ACQUISITION SCHEDULE

Phase 1 construction is anticipated to begin in the summer of 2004. The NFS will require approximately 12 months from the date the PCA is executed to acquire and certify lands available before the respective Phase 1 contracts are advertised (Jun 03 – Jun 04). Phase 1 construction currently includes the following proposed project elements:

- Contract 1—Skookumchuck Dam
- Contract 2—I-5 levees from Mellon St. to Salzer Creek (WA-DOT)
- Contract 3—Airport levee from Salzer Creek to SR-6

Phase 2 construction is planned to commence in the summer of 2005. The NFS will have approximately 24 months to acquire and certify lands available before Phase 2 construction contracts are advertised (Jun 03 – Jun 05). Phase 2 construction currently includes the following proposed project elements:

- Contracts 4, 5 & 6—Salzer Creek levees east of I-5
- Contract 2—Dillenbaugh Creek levees (WA-DOT)

Phase 3 construction is expected to begin in the summer of 2006. The NFS will have approximately 36 months to acquire and certify lands available before Phase 3 construction contracts are advertised (Jun 03 – Jun 06) for the following project elements:

- Contract 4—Ford's Prairie levees
- Contract 4—Skookumchuck River levees
- Contracts 7&8—Project Mitigation Elements including SR-6 Bypass

5.9 Operation and Maintenance Requirements of Selected Plan

The local sponsor, who is responsible for maintenance of the entire project, will be provided with an Operation, Maintenance, Repair, and Rehabilitation Manual (OMR&R) at the time that the project is accepted and turned over to the local sponsor. It will specify what maintenance and estimated rehabilitation required to meet Federal standards. A cost estimate and time schedule will be included for budgeting and planning purposes. It also specifies the consequences of not doing the prescribed maintenance. If the Federal government feels the project is in jeopardy of not functioning due to lack of maintenance, the government will do the work and bill the local sponsor for the effort.

5.9.1 Chehalis/Skookumchuck River Levee System O&M

For the levee system, a minimum of an annual inspection, preferably an inspection after each major flood event, by the sponsor will be submitted to the Corps documenting levee conditions and any repairs or maintenance required or completed. For cost estimating purposes the OMRR&R costs for levees is approximately $8,000 per mile of levee. There is approximately 15 miles of levees and floodwall, proposed in the recommended plan. In addition it is assumed that 50% of the rock will be replaced at year 25. Periodic government inspections will also be done to check that basic Federal standards are being maintained, including:

- No trees over 4-inch diameter,
- Grassed side slopes,
- Annual mowing to allow for ease of inspection,
- Maintained level gravel access road on top of the levee,

- Riprap rock sections will be monitored to assure bank protection, erosion control.

The government will identify any deficiencies in the maintenance or condition of the levee. A specific checklist of work items will be given to the local sponsor spelling out what is required to bring the project back into compliance. Thus making the flood control structure eligible for Federal assistance when major rehabilitation or in the event of flood damage occurs. This includes eligibility for Federal funds thru FEMA after a catastrophic disaster.

The OMRR&R will also include a Flood Fight Plan. Since flood fight efforts are an integral part of the levee system, it becomes critical that the necessary equipment, materials and personnel are available. In addition the plan must specify where flood fight actions need to take place, when to take these actions, and who will be responsible for flood fighting.

This flood fight plan will need to be updated annually with points of contact, material and equipment inventory changes. Problem areas need to be identified and monitored. These documented problem areas should then be incorporated into the next year's maintenance plan.

5.9.2 Skookumchuck Dam O&M

Annual operation and maintenance (O&M) requirements for the flood control operation of Skookumchuck Dam were estimated based on the existing O&M requirements for a similar project, Wynoochee Dam. The Wynoochee Dam is a multi-purpose project that is operated for hydropower, recreation, water supply, and flood control. The Skookumchuck Dam purposes include flood control, water supply and currently limited hydropower (this is to be decommissioned by the local sponsor). As with Wynoochee and several other flood control facilities in the region, during storm events, the USACE will take over flood control regulation of the dam.

The two projects are similar in size, and have fairly similarly sized drainage basins with Wynoochee having 41 square miles and Skookumchuck having about 62 square miles. While the Wynoochee basin is smaller, the basin above Wynoochee Dam is of higher elevation and more mountainous than the basin above Skookumchuck Dam. Flood events at Skookumchuck Dam are not nearly as frequent or intense as events at Wynoochee Dam.

Skookumchuck Dam has no public access, and thus no costs are associated with the operation and maintenance of such facilities. At Skookumchuck Dam there is a small fish trap located at the base of the spillway stilling basin and a minimalist operation to truck fish around the dam. Since only the flood control portion of the O&M costs are of interest here, these additional O&M costs have been excluded from consideration.

The recommended plan includes a gated structure on the spillway, versus the low pool option that would not have this requirement. Therefore there will be additional maintenance and operational expense for the gated structure versus a non-gated structure. The additional maintenance is realized in the form of additional operation requirements (time) given the nature of the watershed. Given a gated spillway, due diligence should be given to ensure appropriate manipulation of the spillway gates during moderate to large events.

The O&M requirements for the flood control portion of Skookumchuck Dam include the following, the annual maintenance, flood control operation, and fish migration due to flood control operations[11]. A 50-year project life was used with a discount rate of 6.125%. Labor rates, including all overhead costs, were assumed to be $75 per hour, which for the selected plan is $108,000 a year. The maintenance costs were estimated at approximately $13,500 per year for the selected plan. The annual costs for Corps regulation is $75,000 per year and for the USGS gaging operations and hydromet operations the cost is $45,000 per year. The costs also include administrative overhead and support. The total annual cost is $633,000 per year.

For flood control operation, it was assumed that there would be one full time person on site during the flood season, and an additional person would be added to the dam site during any storm events. It was also assumed that there would be a person on-site part-time for the remainder of the year. Off-site support and overhead costs, as well as miscellaneous costs and a contingency were accounted for in both cases. Project costs for USACE flood regulation, USGS gaging and hydromet were kept the same as for the Wynoochee Project.

During the flood control season the dam will be operated in accordance with an operation and maintenance manual prepared by Seattle District. An inspection of the project and flood control features would be conducted annually by the Corps to insure that any developing conditions

[11] O&M costs and requirements discussed in this report for Skookumchuck Dam address only the increment of O&M that is attributable to the recommended flood control project. Actual O&M costs to the sponsor will be higher due to O&M costs attributable to other elements of the dam.

which could adversely affect the flood control works are recognized and corrected in a timely manner.

5.9.3 Environmental Mitigation O&M

Operation and maintenance (O&M) for the mitigation features includes four types of activities: 1) replacement of riparian plantings during the first 5 years following construction; 2) removal of non-native species during the first 5 years following construction; 3) maintenance or replacement of livestock fencing; and 4) annual flood damage inspections. Mitigation O&M costs over a fifty year period of analysis were estimated to have a present value of $189,000, or an average annual value of $12,200.

5.9.4 Summary of O&M Costs

The selected plan includes annual O&M costs for its components. The annual O&M cost for each component is presented in Table 5-7. The table also provides a total present value of O&M requirements over the 50-year period of analysis.

TABLE 5-7 OPERATION AND MAINTENANCE COSTS

NED PLAN:	
Annual Chehalis River Levee O&M	$99,500
Annual Skookumchuck River Levee O&M	$19,000
Annual Skookumchuck Dam O&M*	$448,300
Environmental Mitigation O&M	$12,200
Total Annual O&M	$579,000
Present Value O&M Stream	$8,969,200
LOCALLY PREFERRED PLAN:	
Annual Chehalis River Levee O&M	$99,500
Annual Skookumchuck River Levee O&M	$19,000
Annual Skookumchuck Dam O&M*	$514,500
Environmental Mitigation O&M	$12,200
Total Annual O&M	$645,200
Present Value O&M Stream	$9,994,700
**Skookumchuck Dam O&M Cost estimate only include O&M requirements associated with flood control features.*	

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6. IMPLEMENTATION OF SELECTED PLAN

This chapter summarizes cost-sharing requirements and procedures necessary to implement the features of the selected plan.

6.1 Division of Responsibilities for Implementing the Selected Plan

The WRDA of 1986 (PL 99-662) and various administrative policies have established the basis for the division of Federal and non-Federal responsibilities in the construction, operation and maintenance of Federal water resources projects accomplished under the authority of the Corps. This is discussed in detail below. Sections 6.2 and 6.3 specify Federal and non-Federal responsibilities during the preconstruction engineering and design phase (PED) and construction phase.

6.1.1 Federal Responsibilities

The Federal government is responsible for conducting and completing the PED (detailed plans and specifications), advertising and administering the construction contracts after authorization and receipt of Federal and non-Federal funds, and managing the construction phase. The Federal government is responsible for supervisory and administrative support for the non-Federal sponsor's LERRD activities. The Federal government is responsible for project monitoring. The Federal government will provide 65% of the cost sharing for these project costs. The non-Federal sponsor is responsible for funding 35% of the costs of these project costs.

6.1.2 Non-Federal Responsibilities

The non-Federal sponsor is responsible for acquiring all real estate interests required to implement the selected plan. The non-Federal sponsor is not required to provide this real estate until after the PCA is executed. The non-Federal sponsor will provide 35% of the cost sharing for further design, construction, construction management, Federal supervisory and administrative costs, and project monitoring. The non-Federal sponsor will receive credit for in-kind work per Chehalis River and Tributaries, House Report 106-1033 for Public Law 106-554, Section118, which states: *"The project for flood control, Chehalis River and Tributaries, Washington, authorized by section 401(a) of the Water Resources Development Act of 1986 (100 Stat. 4126), is modified to authorize the Secretary of the Army to provide the non-Federal interest credit toward the non-Federal share of the cost of the project the cost of planning, design, and construction work carried out by the non-Federal interest before the date of execution of a cooperation agreement for the project if the Secretary determines that the work is integral to the project.* The non-Federal sponsor is responsible for obtaining all non-Federal permits and authorizations for the construction work. The non-Federal sponsor is responsible for all future operation and maintenance.

6.2 Preconstruction Engineering and Design Phase

6.2.1 PED Procedural Overview

This phase of project development encompasses all planning and engineering necessary for project construction, and may commence after release of the Division Engineer's Public Notice on a favorable study. These studies are required to review the earlier study data, obtain current data, evaluate any changed conditions, establish the most suitable plan for accomplishment of the improvement and establish the basic design of the project features in final detail. Preconstruction planning and engineering studies for projects authorized for construction will be programmed as "continuing" activities.

The results of preconstruction planning and engineering studies are presented in reports identified as "design memorandums." Preparation of design memorandums, and plans and specifications will be cost shared in accordance with the cost sharing required for project construction. Current engineering guidance respecting document preparation and approvals should be consulted. (ER 1110-2-1150) 9-2.

Since PED originally had been initiated prior to the policy change requiring cost sharing of PED, this project is considered "grandfathered" and all PED work will be performed at Federal expense. PED will ultimately be cost shared at the rate for the project to be constructed with any adjustments necessary to bring the non-Federal contribution in line with the proper project cost sharing to be accomplished in the first year of construction.

After receiving Division approval of the project and an allocation of funds for future design studies, the Seattle District will commence further design. If the non-Federal sponsor would like to perform work in-kind during PED, the PED Agreement must be clear on the scope of the local sponsor’s in-kind effort, up to a limit of 35%.

6.2.2 Issues Requiring Additional Study During PED

6.2.2.1 Interior Drainage Analyses

Continued analysis will be conducted during design to analyze the interior drainage of China Creek as it relates to the installation of the levees. At a minimum, the mainline project levee will include "minimum facilities" to relieve local runoff ponding behind the levees for a low Chehalis River condition (i.e. gravity).

In addition, the local community will continue to look at what betterments can be constructed to solve all the flooding issues related to China Creek. The following describes the reconnaissance level study conducted by the local community to identify several alternatives to alleviate flooding in the China Creek Basin. The Corps will work with the community in the design phase to coordinate the design of an interior drainage project with the community’s betterment project.

A reconnaissance level evaluation was conducted to identify potential flood reduction alternatives within the China Creek drainage basin. The following structural flood control and reduction measures were reviewed and evaluated: pumping station, levee, gravity flood flow diversion, dry retention facilities for more storage capacity, channel modifications to increase channel hydraulic capacity, and creek relocation. Non-structural measures were reviewed but not evaluated. A preliminary evaluation of each of these flood reduction measures was conducted to identify potential flood reduction alternatives. The flood reduction measures were then evaluated independently, and in combination, to develop flood reduction alternatives capable of meeting the 100-year flood reduction design criteria. The size, location, flood reduction capability, cost, environmental impacts and benefits, and performance were factors in screening flood reduction measures to develop alternatives for the reconnaissance level evaluations. The construction cost for the 50-year and 25-year flood reduction design criteria was then determined for each alternative. The summary of this analysis is documented below.

A reconnaissance level analysis was conducted to evaluate potential flood damage reduction alternatives. The analysis was conducted to determine potential alternatives for future consideration and evaluation during the next project phase. Table 6-1 provides a summary of estimated cost, 100-year flood flow reduction, pros, and cons for each of the alternatives.

The evaluation indicated that gravity flow diversion and creek relocation from China Creek, near STA 111+01, to the Skookumchuck River is feasible. Construction of a pumping station provides little additional benefit for significant additional cost. The Embankment Dam No. 2 requires substantial real estate acquisition and impacts existing residential neighborhoods. The Gold Street Ring Levee, Lower China Creek Excavation, and China Creek Floodwall do not provide sufficient capacity to be independent alternatives. They could provide economical flood reduction as a supplement to a larger flood reduction measure.

The Flood Flow Diversion, Creek Relocation/Restoration, Gold Street Ring Levee, China Creek Excavation, and China Creek Urban Floodwall flood reduction measures are recommended for further evaluation and refinement during the next project phase. This would include Alternatives No. 8 and 9. In addition, it is recommended that the China Creek channel excavation and floodwall components be evaluated for use with Alternative No. 8 (gravity flow bypass and ring levee) once additional data has been collected.

TABLE 6-1 CHINA CREEK PRE-FEASIBILITY FLOOD REDUCTION ALTERNATIVES EVALUATION

Flood Control Alternative	Preliminary Cost Estimate**	Flood Reduction (STA 55+20)	Pros	Cons
1. Pumping Station No. 1	$10.7 million *($10.7 million)	400 cfs	• Failsafe operation at any flood event • Maximum operational flexibility to provide bypass regardless of Skookumchuck River/China Creek flood stage timing. • Minimal real estate acquisition	• High cost • Maintenance of pumping station • Large pumps required to pump long distance • RR crossing • Coordination & timing of RR crossing construction with BNSF (3rd party)
2. Pumping Station No. 2 with Gold Street Ring Levee	$11.4 million *(11.5 million)	380 cfs	• Failsafe operation at any flood event • Maximum operational flexibility to provide bypass regardless of Skookumchuck River/China Creek flood stage timing. • Minimal real estate acquisition	• High cost • Maintenance of pumping station • Coordination & timing of RR crossing construction with BNSF (3rd party)
3. Embankment Dam No. 1	$7.6 million *(12.1 million)	420 cfs	• Flood reduction for larger length of creek	• Impact to local residential neighborhood/environment • Large real estate acquisition • Environmental impact issues • Impact to Hanaford Road
4. Embankment Dam No. 2 with Pumping Station No. 3	$12.4 million *(13.5 million)	420 cfs	• Pumping Station provides additional capability for controlling peak flows	• High cost • Maintenance of pumping station • Impact to local residential neighborhood/environment • Large real estate acquisition • Impact to Hanaford Road
5. Embankment Dam No. 2 with Gold Street Ring Levee	$7.4 million *(8.6 million)	400 cfs	• Levee provides supplemental flow reduction with minimal impacts to environment and adjacent property owners.	• Impact to local residential neighborhood/environment • Large real estate acquisition • High project cost
6. Embankment Dam No. 2 with Urban Flood Wall	N/A	400 cfs	• Floodwall provides supplemental flow reduction	• Impact to local residential neighborhood/environment • Bridge/culvert rehabilitation cost • Large real estate acquisition cost
7. Embankment Dam No. 2 with Creek Excavation	N/A	400 cfs	• Excavation provides supplemental flow reduction	• Bridge/culvert rehabilitation cost • Sediment deposition would reduce channel capacity

TABLE 6-1 CHINA CREEK PRE-FEASIBILITY FLOOD REDUCTION ALTERNATIVES EVALUATION

Flood Control Alternative	Preliminary Cost Estimate**	Flood Reduction (STA 55+20)	Pros	Cons
8. Flood Flow Diversion with Gold Street Ring Levee	$7.3 million *(7.8 million)	395 cfs	• Low Cost • Minimal maintenance • Minimal land acquisition	• More detailed data collection and hydrologic analysis required to verify Skookumchuck River/China Creek flood stage timing • Coordination & timing of RR crossing construction with BNSF (3rd party)
9. Creek Relocation/ Restoration with Gold Street Ring Levee	$9.6 million *(11.9 million)	590 cfs (diversion of entire flow)	• Stream/habitat restoration • Reduced China Creek bridge/culvert rehabilitation construction costs • Increased public shoreline access • Low maintenance	• Coordination & timing of RR bridge reconstruction at new location with BNSF (3rd party) • Impact to residential neighborhood • More detailed data collection and hydrologic analysis

*Cost includes assumed $18,000/acre real estate acquisition and $100,000/structure acquisition costs.
**Costs are based on 100-year flow or 1996 flood event.

6.2.2.2 Skookumchuck Dam Stability Evaluation

The Corps conducted Skookumchuck Dam geotechnical investigations in 2001. The results of these studies identified potential dam stability issues as a result of a seismic event that will require further analysis.

During original construction of the dam, while stripping the foundation, a deposit of silt north of the original river channel was discovered. The initial exploration programs for the dam did not reveal the silt layer. An exploration program was undertaken to define the extent and thickness of this silt deposit. A decision during construction of the dam was made to leave the silt layer alone. After 20 to 25 feet of embankment material was placed on the silt layer, there were indications that embankments would become unstable in their original design. It was judged that the silt body could be contained and stabilized by adding massive toe berms where the embankment shells are founded on the silty clay material; these were constructed.

In the investigations conducted by the Corps in 2001, based on recent seismic information, the study concluded that the sandy gravel soils underlying the silts appear to be liquefiable under all design Maximum Credible Earthquake (MCE) ground motions. In 2001, a similar stability analysis was performed utilizing subsurface explorations, the liquefaction data, and seismic hazard analysis from recent studies. This included evaluation of the existing static and post-seismic stability of the downstream slopes of the dam and berm using a limit-equilibrium approach. The extent of liquefied soils is uncertain beyond the area of investigations with Becker and SPT borings, thus slope failures were calculated for five different ranges of liquefied soils. The calculations indicate a factor-of-safety below 1.0 for conditions where liquefied soils are present from the core to the toe of the downstream berm.

Currently, FERC is reviewing the information provided by Pacificorps (the current owner) as required by the regulatory permit for operating a hydroelectric facility and the results of the Corps investigation described in the above paragraph. Based on a May 17th meeting with FERC, the regulatory agency will be issuing a letter to the owner in June 2002 recommending that they conduct further investigations to determine the extent of the liquefiable material. Based on this investigation the owner will be required to conduct remediation to the downstream berm to ensure that the dam meets dam safety requirements in a post seismic event. The current owner prior to the local sponsor taking ownership of the facility will conduct this effort. This remediation effort will be 100% cost to the current owner and the costs are not NED costs and are not included in the cost estimate for the selected plan.

6.3 Construction Phase

6.3.1 Project Cooperation Agreement

The PCA will define the non-Federal sponsor's responsibility to provide all lands, easements, rights-of-way, and suitable borrow and dredged or excavated material disposal areas required for the project (collectively referred to as LERRD requirements; see Section 101(a) and (e), Section 103(a) and (j) of P.L. 99-662). The value of the required LERRD provided by the non-Federal sponsor will be credited against the non-Federal sponsor's percentage share of the costs of construction. The portion of the non-Federal sponsor's required share of costs that remains after LERRD credit is afforded must be paid to the Government in cash.

The PCA for the project will be negotiated between representatives of the district and the non-Federal sponsor. Once the project is authorized for construction, the budget/appropriations process drives the PCA process. Current policy dictates that PCAs will not be executed until: (1) the project document has been approved by HQUSACE; (2) the project is budgeted as a new construction start or construction funds are added by Congress, apportioned by OMB, and their allocation approved by ASA(CW); (3) documentation of compliance with the National Environmental Policy Act (NEPA) and other associated environmental laws and statutes in the PCA checklist has been furnished; and (4) the draft PCA has been reviewed and approved by ASA(CW).

All Civil Works projects are managed, planned, and executed under the Life Cycle Project Management System (LCPM) (ER 5-1-11). Consistent with ER 5-1-11, the forecast final cost estimate to be entered into PCAs for all specifically authorized new starts is based on the most current cost estimate prepared in accordance with the Micro-Computer Aided Cost Estimating System (M-CACES) in the Code of Accounts format.

Under the terms of the PCA, when the Government determines that the entire project, or functional portion thereof, is complete, the Government will provide written notice to the non-

Federal sponsor of such determination and furnish an Operations, Maintenance, Repair, Replacement, and Rehabilitation (OMRR&R) Manual to the non-Federal sponsor. The non-Federal sponsor is then responsible for the OMRR&R of the project, or functional portion. After completion and notice to the non-Federal sponsor, authority is considered to expire for expenditure of Federal funds for construction of additional improvements on the project or for maintenance thereof.

6.3.2 Project Construction

Construction is expected to occur over a period of 3 years (2004 –2007). The non-Federal sponsor must provide all of their cost-sharing funds and real estate at the beginning of construction (prior to award of construction contracts) unless they specifically request a change to the PCA to allow provision of funds in a phased manner similar to the construction schedule.

Table 6-2 provides an estimated timeline from the release of a positive Chief of Engineers Report to project completion.

TABLE 6-2 CONSTRUCTION SEQUENCING

Description	**Dates**
Chief's Report	Dec 02
All Permits Received	June 03
Project Cooperation Agreement Signed With Sponsor	June 03
Corps Receives Construction Funding	Jan 04
Sponsor Completes Real Estate Acquisition (phase 1 will be completed in June 03)	June 06
Corps Advertises Construction Contract (First Contract)	June 04
Construction Contract Award (First Contract)	July 04
Contract Notice To Proceed: Phase1. Skookumchuck Dam I-5 levees from Mellon St. to Salzer Creek (WA-DOT) Airport levee from Salzer Creek to SR-6 Phase 2. Salzer Creek levees east of I-5 Dillenbaugh Creek levees (WA-DOT) Phase 3. Ford's Prairie levees	 July 04 July 04 July 04 July 05 July 05 July 06

TABLE 6-2 CONSTRUCTION SEQUENCING

Description	Dates
Skookumchuck River levees	July 06
Project Mitigation Elements including SR-6 Bypass	July 06
Approve Contractors Plans (Safety, Health and Environmental Protection) for	
Phase1.	
Skookumchuck Dam	July 04
I-5 levees from Mellon St. to Salzer Creek (WA-DOT)	July 04
Airport levee from Salzer Creek to SR-6	July 04
Phase 2.	
Salzer Creek levees east of I-5	July 05
Dillenbaugh Creek levees (WA-DOT)	July 05
Phase 3.	
Ford's Prairie levees	July 06
Skookumchuck River levees	July 06
Project Mitigation Elements including SR-6 Bypass	July 06
Construction Contract Complete	
Phase1.	
Skookumchuck Dam	Oct 05
I-5 levees from Mellon St. to Salzer Creek (WA-DOT)	Oct 04
Airport levee from Salzer Creek to SR-6	Oct 06
Phase 2.	
Salzer Creek levees east of I-5	Oct 06
Dillenbaugh Creek levees (WA-DOT)	Oct 05
Phase 3.	
Ford's Prairie levees	Oct 06
Skookumchuck River levees	Oct 04
Project Mitigation Elements including SR-6 Bypass	Oct 05
Project Construction Physically Complete	Aug 07
Project Fiscally Complete	Oct 07
Final Acceptance & Transfer to Local Sponsor	Oct 07

6.4 Operation and Maintenance

The non-Federal sponsor(s) is responsible for all future operation and maintenance activities. An Operation and Maintenance Manual will be developed during construction and provided to the

County for implementation. The estimated total cost of O&M is $9,994,700 with an average annual equivalent value of $645,200. See Section 5.9 for further discussion of operation and maintenance.

6.5 Cost Allocation

Cost allocation is the practice of allocating the separable costs of a project to the various project purposes they serve. Because all features of the selected plan were formulated to address flood damage reduction objectives (or to mitigate for adverse environmental impacts) all costs are allocated to the authorized project purpose of Flood Damage Reduction. NED costs (economic costs that include opportunity costs) are used for cost allocation.

6.6 Cost Apportionment

Cost apportionment is the practice of dividing the responsibility for paying the costs of a project between the Federal government and the local sponsor (or appropriate non-Federal interests). Project financial costs (non-NED costs) are the costs that are shared by the planning partners. Cost sharing for construction of this project will be in keeping with current Corps of Engineers policy whereby for flood damage reduction projects, the non-Federal share will be 35 percent of the project implementation costs (PED, construction, construction management, Federal supervision and administration, and monitoring). The non-Federal sponsor will provide 100 percent of the necessary lands, easements, rights-of-way, relocations and disposal areas (LERRDs), and conduct all future operation, maintenance, repair, rehabilitation and replacement (OMRR&R) activities. If the LERRD value exceeds the 35 percent share required from the non-Federal sponsor, the sponsor will be reimbursed for the value of the LERRD that exceeds the 35 percent share. If this situation is estimated prior to executing the PCA, no additional credit will be given to the sponsor for in-kind services.

Table 6-3 provides a summary of the estimated cost apportionment between the Federal and non-Federal interests for the recommended plan. The table shows the total first cost of the recommended project as $97,107,000 of which $58,672,250 is Federal cost and $38,434,750 is non-Federal cost. The non-Federal cost includes the sponsor's cash contribution of $24,164,750 and the LERRD value of $14,270,000.

TABLE 6-3 CHEHALIS RIVER FLOOD DAMAGE REDUCTION COST APPORTIONMENT

	Federal Cost*	Non-Federal Cost*	Total*
NED Flood Damage Reduction and Mitigation	$58,672,250	$31,592,750	$90,265,000
Plus Incremental Flood Damage Reduction and Mitigation Buy-up to Locally Preferred Plan (LPP)		$6,842,000	$6,842,000
Less LERRD Value		$14,270,000	$14,270,000
LPP Cash Contribution	$58,672,250	$24,164,750	$82,837,000
Recommended Project (Locally Preferred Plan)	$58,672,250	$38,434,750	$97,107,000

Apportionment of financial costs
**March FY02 Price level (rounded) – Cost is project costs less OMRR&R*

6.7 Institutional Requirements

Before the PCA can be executed, the local sponsor will prepare the following financial analysis:

- The local sponsor's project-related yearly cash flows (both expenditures and receipts where cost recovery are proposed), including provisions for anticipated operation and maintenance requirements and contingencies for uncertain damages from natural events;
- The local sponsor's current and projected ability to finance its share of the project cost and to carry out project implementation and OMRR&R responsibilities;
- The means and certainty for raising additional non-Federal financial resources including but not limited to special assessment districts and state grants;
- The steps that the local sponsor would take to ensure it would be prepared to execute its project-related responsibilities at the time of project implementation.

In addition, as part of any PCA, the local sponsor would be required to undertake to save and hold harmless the Federal government against all claims related to environmental restoration, and other activities associated with this project.

6.8 Environmental Requirements

There are many Federal, state, tribal and local laws, regulations and treaties applicable to the selected plan. Attached to this general reevaluation report are an EIS and a Fish and Wildlife Coordination Act Report that programmatically satisfy NEPA requirements when a Record of Decision (ROD) is signed. Projects will achieve the design level required to complete a 404(b)(1) analysis during PED. In all cases where a 404(b)(1) is needed, it will be fully developed on a site-specific basis prior to construction and will be completed prior to construction. The Corps will coordinate with the State Department of Ecology and Chehalis Tribe to obtain Section 401 state water quality certification. Certification is usually done during PED (about 90% design level) when necessary information is developed. The Corps has requested a letter of support from the Department of Ecology. Table 6-4 below shows that status and responsibility for compliance with the applicable laws, regulations and treaties.

TABLE 6-4 STATUS OF COMPLIANCE WITH ENVIRONMENTAL LAWS/REGULATIONS/TREATIES

Law/Regulation/Treaty	Status of Compliance
National Environmental Policy Act (NEPA)	Will be complete after programmatic EIS is approved and ROD is signed.
Endangered Species Act	Consultation on-going, to be completed for the final report
National Historic Preservation Act	Consultation on-going
Clean Water Act	A 404(b)(1) analysis will be prepared in PED and NPDES construction permits will be obtained
Clean Air Act	In compliance
Fish and Wildlife Coordination Act	In compliance
Migratory Bird Treaty Act	In compliance
Executive Order 12898, Environmental Justice	In compliance
Executive Order 11990, Protection of Wetlands	In compliance
Executive Order 11988, Floodplain Management	In progress, floodplain management plan to be completed prior to PCA
Indian Treaty Rights	Will be in compliance through public review process
State Environmental Policy Act	Lewis County will adopt Final EIS
Washington Hydraulic Code	Lewis County will obtain required permits
Water Quality Certification	Corps will obtain required permits
Growth Management Act	In progress
Model Toxics Control Act	Lewis County will obtain any necessary approvals
State Aquatic Lands Management Laws	Consultation on-going
Lewis County Regulations	Lewis County will obtain all required permits
City Regulations and Ordinances	Lewis County will obtain all required permits

6.9 Sponsorship Agreements

The non-Federal sponsor (Lewis County) has provided a letter of intent acknowledging sponsorship requirements of the project. The County and the Corps will sign a PED agreement defining scope and responsibilities of each party for the preconstruction engineering design phase. Prior to the award of construction contracts, the sponsor will be required to execute the Project Cooperation Agreement and provide required funds.

6.10 Sponsor's Financial Plan and Capability Assessment

In accordance with ER 1005-2-100, paragraph 6-184.b, a preliminary financing plan and statement of financial capability were prepared by the local sponsor. The District has reviewed the plan and assessed the sponsor's understanding of the budgetary issues related to financing the proposed project. The District has determined that the local sponsor has the capability to fund their portion of implementation responsibilities.

6.10.1 Financial Analysis

Lewis County, the official non-Federal sponsor, is willing and able to share the costs of project implementation. As shown in Table 6-3, the cost estimate for the NED Plan is $90,265,000. The sponsor is responsible for 35% of the implementation cost, an estimated $31,592,750. Assuming that the real estate value the sponsor will get credit for is $14,270,000, and will get credit for the $3,000,000 already contributed, Lewis County would be responsible to provide the Corps of Engineers an additional $14,322,750 in cash over the construction period for the NED Project. The sponsor, however, has expressed an interest to upgrade portions of the NED Plan to provide additional levels of flood protection. These upgrades (buy-ups) are a 100% local responsibility, and are estimated to add $6,842,000 in costs to the NED Plan. Therefore, the total cash responsibility of the sponsor, if they continue to support the betterments and after crediting of LERRD and already contributed funds, may be as much as $21,164,750. Cost estimates do change over time, and the final cost sharing numbers would be determined at the end of construction.

Despite the fact that Lewis County is the official sponsor and will be signing the Project Cooperation Agreement (PCA) with the Corps of Engineers, the County is expecting to receive the majority of its required project funds from the Washington State Department of Transportation (WSDOT). This source of funding, as well as other sources of non-Federal project matching funds are discussed in the County's *Financing Plan and Statement of Financial Capability*, provided by letter to Seattle District, dated August 13, 2002.

6.10.2 Assessment of Financial Capability

The Corps' assessment of the local sponsor's financial capability is required to verify that sufficient funds will be available to the sponsor to satisfy the financial obligations for the project. The financing plan submitted by Lewis County is satisfactory and sufficient.

The county intends to fund its land acquisition expenses, cash contribution requirements, and annual operation and maintenance costs from the following sources:

1. Washington State Department of Transportation funding.
2. Creation of a Flood Control District (or similar local service district with taxing authority), or in the event sufficient funds are not available through these sources,
3. Enter into an interlocal agreement with the Cities of Centralia and Chehalis to assist in funding.
4. Issue General Obligation Bonds.

An allocation of funds table will be included prior to the signing of the PCA.

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7. LEGAL AND TECHNICAL REVIEW

The study's Quality Control (QC) Plan defined the process to assure quality products for the General Reevaluation Study. This QC Plan defined the responsibilities and roles of each member on along with a legal sufficiency and policy compliance review. ITR will be the project and the Independent Technical Review (ITR) team. Under current procedures, ITR is a district function conducted for all decision documents and will be independent of the technical production of the product/project.

The project team is comprised of qualified staff from within the Seattle District, Northwestern Division, the project sponsor--Lewis County, the USF&WS, and their consultants and contractors. The ITR team was selected on the basis of having the proper knowledge, skills, and experience necessary to perform the task and their lack of direct affiliation with the development of the GRR/EIS. The ITR included periodic technical review team meetings to discuss critical plan formulation or other project decisions, and coordinate the review of the written GRR, EIS, appendices, report documentation and files. The objective of ITR was to ensure and confirm that:

- The documents are consistent with established criteria, procedures and policy;
- Assumptions that are clearly justified have been utilized in accordance with established guidance and policy, with any deviations clearly identified and properly approved;
- The concepts, features, analytical methods, analyses, and details are appropriate, fully coordinated, and correct;
- The problems/issues are properly defined and scoped; and
- The conclusions and recommendations are reasonable.

The ITR was divided into two major segments. The first part of the ITR took place in July 2001 and covered the basic hydrology, hydraulics, and economic analysis involved in developing the existing condition analyses and determining the appropriate "without-project" analysis. In addition, an ITR of Skookumchuck Dam liquefaction and stability analysis was also conducted to ensure that Corps dam stability criteria would be met. The second part of the ITR concentrated on review of the draft completed technical reports and covered all other aspects of project planning and design.

A Certification of Technical and Legal Review memorandum is on file with the Seattle District Project Manager. This memorandum includes:

- A Statement of Technical and Legal Review that discusses the general scope of the review and lists the ITR team members
- A Certification of ITR that identifies the significant technical concerns raised during the review and the resolution of those concerns and is signed by the District Chiefs of Planning, Engineering, Operations, and Real Estate.
- A Certification of Legal Review of all documents and their legal sufficiency, signed by a District Office of Counsel attorney.

8. DISTRICT COMMANDER'S RECOMMENDATION

The cities of Chehalis, Centralia, and surrounding communities in Lewis and Thurston Counties, Washington have a long history of flooding and flood damages. These problems have been acknowledged and studied for many years. More recently, heightened environmental awareness and the potential listing of area aquatic species as threatened and endangered have resulted in a need for increased focus on the development of flood control alternatives that minimize environmental impacts and that incorporate environmental features to mitigate any adverse impacts to fish and wildlife habitats.

The recommended project is the Locally Preferred Plan as described in his report. It will provide 100-year flood protection for the cities of Centralia and Chehalis, Washington. The project will provide estimated annual benefits of $8,765,000, including $6.5 million in flood related damages to structures and their contents, $2.1 million in annual avoided costs associated with the need to elevate Interstate Highway 5 without the project, and an annual reduction of $129,000 in traffic delays related to flooding. Annual economic costs are estimated at $7,220,000, resulting in annual net benefits of $1,545,000 and a positive benefit to cost ratio of 1.21 to 1. The NED Plan costs $6,700,000, providing net benefits of $2,065,000 at a benefit to cost ratio of 1.31 to 1. The recommended project is supported by the local sponsor, Lewis County, Washington who will assume all costs over those of the NED Plan as identified in this report.

I recommend that the selected plan described herein for flood damage reduction purposes be authorized for implementation as a Federal project. The implementation cost of the project is currently estimated at $97,107,000. The Federal share is currently estimated at $58,672,250 and the non-Federal share is $38,434,750. (These costs are in March 2002 price level).

The recommendations contained herein reflect the information available at this time and current departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to the Congress as proposals for authorization and implementation funding. However, prior to transmittal to the Congress, the sponsor, the States, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

Colonel Ralph H. Graves
U.S. Army Corps of Engineers
District Engineer